Capital Investments Proposal

December 2021

ComEd

An Exelon Company

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Purpose of this Document

Commonwealth Edison Company (ComEd) presents this Capital Investments Proposal and supporting data in compliance with Section 16-105.17(e)(5) of the Illinois Clean Energy Law (Clean Energy Law) and the rules of the Illinois Commerce Commission (ICC), which call for the submission of preliminary capital plans in advance of the stakeholder process.[1] The information contained herein is preliminary and subject to change in response to changed circumstances, in accordance with ComEd's planning process, and in light of feedback that ComEd will receive as it formulates its Multi-Year Integrated Grid Plan (MYIGP or the Grid Plan) and as part of the Plan Development Stakeholder Process (MYIGP Workshops). As the Clean Energy Law recognizes, all information provided in this Capital Investments Proposal is informational, includes estimates and projections, and is intended to provide a preliminary view of costs and estimates for the stakeholder process. The information may change and evolve as a result of many factors, including as a result of this process, and while the information is accurate at this time, it is not binding.

In accordance with the requirements set forth in the Clean Energy Law and the ICC's rules, ComEd provides supporting data in conjunction with this Capital Investments Proposal that falls in three categories:

A. A review of ComEd's planned capital investments and supporting data;
B. A review of how ComEd plans to invest in its distribution system to meet the system's projected needs; and
C. A review of the system and locational data regarding reliability, resiliency, Distributed Energy Resources (DER), and service quality.[2]

ComEd provides the supporting data described in subparts A and B above in Sections 2.2, 2.3, and 3 of this Capital Investments Proposal and in Appendix B. ComEd provides the supporting data described in subpart C above in Section 2.5 of this Capital Investments Proposal.

In addition, in compliance with the ICC's rules, ComEd also provides information identifying "proceedings before the Commission that include information that will aid in the analysis of the Utility's Electric Distribution System capital projects placed into service in the proceeding nine (9) years" in Appendix C.[3] ComEd continues to identify, gather, and/or develop other information to support this process, including additional information responsive to Section 475.100(e) of the ICC's rules, and will provide such information as it becomes available. Finally, also in compliance with the ICC's rules, ComEd has separately submitted "public versions of data provided by the Utility to the auditor conducting the Baseline Grid Assessment pursuant to Section 16-105.10 of the Act."[4]

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[1] See 220 ILCS 5/16-105.17(e)(5) and 83 Ill. Admin. Code §475.100.

[2] See 220 ILCS 5/16-105.17(e)(5) and (e)(2)(A)-(C) and 83 Ill. Admin. Code §475.100(a)-(c).

[3] 83 Ill. Admin. Code § 475.100(d).

[4] 83 Ill. Admin. Code § 475.100(f).

Executive Summary

ComEd's Capital Investments Proposal is intended to ensure that ComEd can maintain grid performance and further enhance capabilities that support Illinois' policy goals, including those described in the Clean Energy Law. Among these are maintaining adequate, reliable, and affordable electric service; integrating additional DER; supporting beneficial electrification; and augmenting resilience to mitigate the severe weather effects of climate change, as well as emerging cyber and physical threats.[5]

The investments described here are based on ComEd's assessment of key grid and customer needs in its service territory, new technology developments, and relevant technology trends and best practices. The Capital Investments Proposal will support the stakeholder process that is envisioned as part of the Clean Energy Law, which may inform the development of the Grid Plan. Grid planning remains a continuous process. While the future Grid Plan is developed with a medium- to long-range horizon, it will be periodically adjusted as conditions change.

ComEd is responsible for the safe and reliable operation of the distribution grid, and grid planning is a core utility function. That responsibility entails operating a vast, complex, and aging grid infrastructure. Much of this system was designed and deployed decades before the wide-scale adoption of DER, the recent rise in electrified transportation, evolving customer expectations for digital interactions and desires for self-service options, and emerging challenges caused by climate change and cyber threats. Operational challenges introduced by these new technologies and customer demands require process refinements to plan, engineer, and design the grid's capabilities in advance of its changing uses.

The ComEd grid planning process is rooted in an understanding of existing grid conditions and needs. The process includes forecasting of the grid needs in the future, and then prioritizes the projects based on expected costs and benefits. ComEd's planning process focuses on addressing evolving electrical grid changes and supporting the goals of State policies and initiatives. The planning process is designed to enable ComEd to meet the challenges stemming from climate change, provide higher levels of resiliency to our customers, improve air quality across our service territory, and uplift all communities that ComEd serves.

[5] Distribution system reliability has defined metrics such as SAIDI, CAIDI, SAIFI, and CAIFI, which are explained in more detail later in this document, and which measure the reliability of supply considering disruptions that are "normal" and "expected" during the course of a year. Resilience is defined by FERC / IEEE as "The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event." https://www.naesco.org/data/industryreports/DOE-IEEE_Resilience%20Paper_10-30-2020%20for%20publication.pdf

1 Introduction

Grid planning is an increasingly holistic, complex, and dynamic process that endeavors to accommodate changing customer needs while adapting the grid to continue providing a reliable, resilient, and safe service. It occurs at both the transmission and distribution level.

Planning and operating the distribution grid are core functions of electric utilities. Planning of the distribution system considers various drivers, including, but not limited to, safety, reliability, operational flexibility, resilience, existing design and infrastructure, capacity needs, asset conditions, and cost efficiency.

Distribution system capital investments are intended not only to satisfy current obligations but also to prepare ComEd's system for the future. The Capital Investments Proposal, which may inform the Grid Plan, is intended to identify investments to meet ComEd's service obligations and to achieve the State's policy goals, including those established by the Clean Energy Law. The outcome from this process, and the collective input from stakeholders provided through the workshop process, may further inform ComEd's Grid Plan.

Grid planning continues to evolve to address new opportunities with clean energy technologies while addressing old and new challenges. These opportunities and challenges include decarbonization through the integration of additional clean energy technologies, as well as adaptation to the impacts of climate change and other emerging challenges. Doing so may require changes to equipment standards, technologies, and projects to cost-effectively meet evolving needs for grid performance and timely execution of work, in addition to improved coordination between transmission and distribution grid planning. Decisions made in some aspects of planning will affect the energy ecosystem, requiring additional changes going forward. For example, integrating additional electric vehicle supply equipment (EVSE) can lead to faster EV adoption and more usage, which will require additional EVSE integration.

Section 2 of this Capital Investments Proposal provides a historical review of ComEd's distribution grid and describes the current operational conditions. Specifically, the section details long-established investments by category: corrective maintenance (primarily repair and replacement), new business connections (for new customers), facility relocations (to support federal, State, country, and municipal improvement projects), capacity expansion (to address observed load growth, reliability needs, etc.) and system performance (to address distribution system degradation and target continuous improvement in reliability, resiliency, safety, and electric grid health). Additionally, there are ongoing investments in vehicle purchases, real estate and facilities, tools, and customer operations and IT systems, all of which are needed to support reliable operations and dependable customer service. The investment categories are described for the past four years. Investments are described in terms of the grid needs and the objectives established in terms of maintaining and improving grid capabilities and performance. The section also discusses benefits that these investments brought to ComEd customers.

Section 3 describes the key priorities in the electrical distribution system today and in the immediate future, including, but not limited to:

- Resilience and reliability in the face of severe weather events and other potentially disruptive events, including cyber and physical security challenges;
- Integration of high levels of DER while maintaining a secure, safe, and reliable grid;
- Rapid beneficial electrification of transportation, buildings, and industrial end uses that have traditionally relied on fossil fuels;

- Continued digital transformation to meet the changing service needs of our customers; and
- Sharing the economic and service benefits of the modernized grid with all communities.

This Capital Investments Proposal also describes technologies and applications that integrate customer owned DER into the grid, limit future service interruptions, and facilitate faster service restoration. Customers will benefit from these investments through improved performance and forecasted reductions in interconnection costs. ComEd investments in tools and methodologies for planning and incorporating these technologies will facilitate their introduction and deployment into the distribution grid, accelerating the benefits that they bring and uplifting all communities that ComEd serves.

Additionally, there are three appendices. Appendix A is a glossary of the terms and abbreviations used throughout this document. Appendix B contains a selection of relevant ComEd planning processes and procedures for reference. Appendix C contains a list of docketed proceedings before the Commission, as required by Section 475.100(d) of the Commission's Rules.

The investments and programs described herein pertain solely to the distribution grid. There are additional investments and programs that focus on the transmission system, the backbone of the grid, but these are excluded from the scope of this Capital Investments Proposal.

2 Present Grid Conditions and Processes

ComEd operates a power delivery system that serves the third-largest metropolitan area in the United States and one which must adapt to large climatological swings and extreme weather events. Weather in the Chicago region varies significantly from hot, humid, and wet summers to freezing, snowy, and windy winters. For instance, the 2019 minimum and maximum temperatures were - 23°F and 97°F, a range of 120°F, which puts tremendous strain on grid planning and operation.

As illustrated in Figure 2-1 below, the frequency of natural disasters in Illinois with costs exceeding $1 billion has increased over the past 40 years, with more than half of the $1 billion+ disasters occurring since 2010.

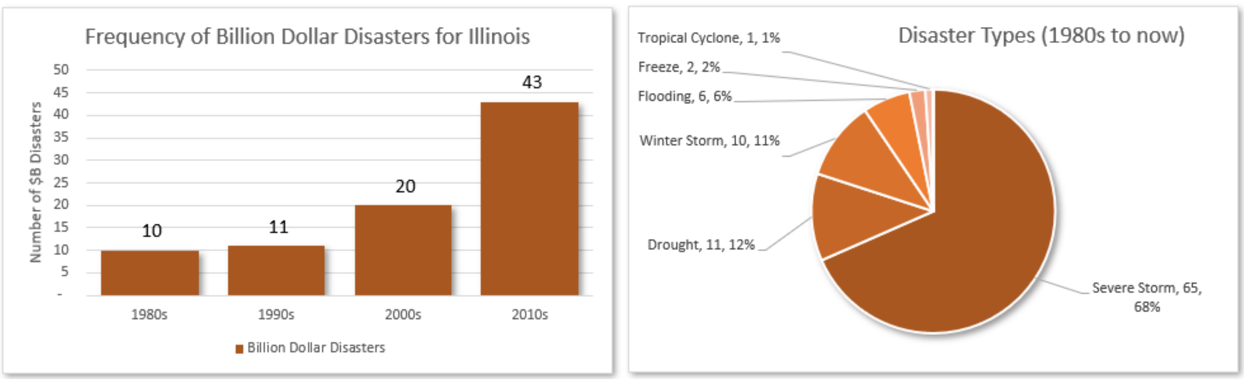


Figure 2-1. Frequency and Type of Billion Dollar Disasters in Illinois (1980 to present)[6]

Most of the costs shown in Figure 2-1 are associated with events with the capacity to damage the distribution grid – severe storms, winter storms, and flooding. The evolving risk profile of a changing climate has the potential to increase grid vulnerability and the frequency of these disasters even further.[7]

2.1 System Description

ComEd is the fourth largest electric utility in the United States by number of customers. ComEd's power-delivery system serves over 4 million customers or 70 percent of the State's population, is very diverse (e.g., different distribution voltage levels, construction types, etc.), and provides service to metropolitan, suburban, and rural areas. The table below provides a summary of key system attributes as of 2020.

[6] Billion Dollar Weather and Climate Disasters, National Centers for Environmental Information. https://www.ncdc.noaa.gov/billions/

[7] Id.

Table 2-1. Key ComEd System Attributes

System Parameter	Approximate Values
Number of customers	4.1 million
City of Chicago	1.3 million
Active meters	4.2 million
Square miles of service territory	11,400
Peak load in MW (Occurred on 7/20/2011)	23,753
Number of substations	800
Total circuit miles (Low voltage 4/12/34/69kV)	108,400
Number of distribution poles	1.3 million
Number of distribution manholes	35,500
Number of distribution transformers in service	506,600

Managing this grid requires the dedicated work of ComEd employees and qualified contractors and requires ComEd to invest in the grid. Since accelerating smart grid investments in 2012, ComEd has achieved best-on-record customer satisfaction, primarily driven by improvements in reliability and reasonable rates. These investments have also avoided more than 16 million customer interruptions throughout the system due in part to smart grid and system improvements. The avoided customer interruptions from the investments in the grid have resulted in at least $2.7 billion in estimated societal savings.[8]

2.2 ComEd's Existing Grid Planning Process

Capital and O&M Planning Process Overview

ComEd's investment planning process is a complex, interrelated process that reflects the impacts of inspections, repairs, and asset replacement strategy. Each year, ComEd updates and reviews a five-year forward-looking capital and O&M budget designed to achieve ComEd's operational and compliance objectives. That planning process includes: 1) updating and refining the Long-Range Plan (LRP), which incorporates a rolling, five-year, forward-looking investment plan, and 2) challenging cost / benefit / risk assumptions of proposed investments in the LRP through a series of review sessions. Additionally, once investments secure funding approval within the five-year forward-looking investment LRP, the individual investments are reviewed and challenged again as they progress towards construction and being placed in service.

Investment Categories, Sub-Categories, and Planning Framework

ComEd's LRP is separated into areas of spending that, in effect, group similar types of work into what ComEd calls Investment Categories. To further align investment planning and execution with responsible departments and disciplines, ComEd separates Investment Categories into discipline-specific groups or Sub-Categories.

[8] Based on Ernest Orlando Lawrence Berkeley National Laboratory 2009 and 2015 reports documents titled "Value of Service Reliability Estimates for Electric Utility Customers in the United States." https://www.icecalculator.com/documentation. Measuring additional value attributes would increase this value.

Core distribution system Investment and Sub-Categories are briefly described in the table below and are also discussed in more detail in Section 2.3. Note that the Subcategory description is in no way an indication of capital investment functionalization as it is not uncommon for distribution system investments to be planned and managed from Subcategories that have “transmission” in the title (e.g., high-voltage distribution).[9]

Table 2-2. Distribution System Investments and Subcategories

Distribution System Investment and Sub Categories		
Investment Category	**Investment Category Definition**	**Subcategories**
Capacity Expansion	Investments are required to expand, reinforce or reconfigure the grid so that system meets customer capacity (load) requirements	Capacity Expansion – Distribution Capacity Expansion – Transmission*
Corrective Maintenance	Reactive investments to correct degraded or failed system equipment or component conditions that render them incapable of performing their designed function	Corrective Maintenance – Distribution Corrective Maintenance – Substation Corrective Maintenance – Transmission*
Customer Operations	Investments related to meter installations/exchanges	Customer Field Operations Customer Operations
Facility Relocation	ComEd facilities relocation to resolve conflicts in public rights of way as initiated by planned governmental agency public improvement projects	Facility Relocation
New Business Connections	Investments to connect new customers, upgrade existing customers’ service, or relocate non-municipal services	New Business
Preventative Maintenance²	Investments to keep the system in proper operating condition and avoid/reduce failures that include outage and safety risks. Includes trimming and removal of trees and other vegetation for the distribution and transmission systems, as well as grounds maintenance at substations, rights-of-way, and ComEd facilities.	Preventative Maintenance - Distribution Preventative Maintenance – Transmission & Substation Vegetation Management
System Performance	Investments that address obsolescence, degradation and target continuous improvement in the reliability, resiliency, safety, and health of the electric grid	System Performance – Distribution System Performance – Protection & Control System Performance - Substation System Performance – Transmission* Utility Advancement†

*High-Voltage Distribution only.
² Preventative Maintenance is O&M and does not contain capital investments.
†”Utility Advancement” is defined as investments in technology that demonstrate clean DER integration onto the ComEd distribution system and mitigate impacts of climate change.

Process for Identifying and Prioritizing Investments

ComEd has developed and implemented investment and maintenance programs that are based on internal experience, historical trends, industry best practices, and manufacturer recommendations. Industry practices are selectively incorporated from institutions including the

[9] “Functionalization” refers to the separation of delivery assets and functions between distribution and transmission and is governed by the Federal Energy Regulatory Commission (“FERC”) “Seven Factor Test.” The Seven Factor Test refers to seven indicators identified in FERC’s Order No. 888, which determine what is local distribution and thus subject to State jurisdiction.

Centre for Energy Advancement through Technological Innovation (CEATI), the Electric Power Research Institute (EPRI), the Institute of Electrical and Electronics Engineers (IEEE), and the North American Transmission Forum (NATF), among others.

ComEd uses a material condition improvement approach that includes a periodic assessment of key transmission, substation, and distribution asset categories based on a standard and repeatable process called "Health Indexing." This approach utilizes the collection and interpretation of performance data for computing Health Indices of its major transmission and distribution (T&D) assets based primarily on available historical inspection data, loading history, and past performance of the assets.

Health Indexing determines equipment condition based on criteria designed to identify effects of long-term degradation that cumulatively lead to an asset's end-of-life. It provides a quantitative indication of the condition of an asset that is more objective and meaningful than simply relying on one criterion, such as equipment age. This approach also allows capital expenditure planning to consider the impact of varying environmental aging factors.

ComEd prioritizes equipment investments based upon an objective risk assessment that combines the impact (consequences) of the potential failure with the likelihood (or probability) of that failure occurring. The portfolio risk matrix, shown in the figure below, quantifies the "impact (consequences)" and "likelihood (probability)" of a failure on a scale from low to high. Combining health indexing with risk modeling allows ComEd to target investments and work where they will provide the most benefit to customers.

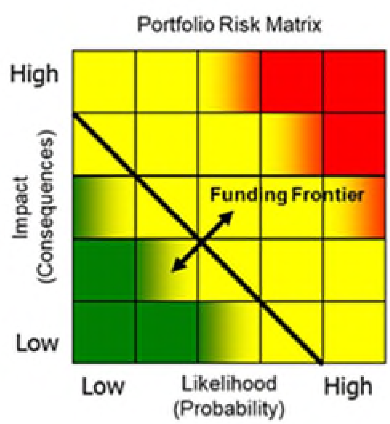


Figure 2-2. Portfolio Risk Matrix

As illustrated, projects with a High "impact" and High "likelihood" will have the highest risk score (red shaded region of the portfolio risk matrix) while projects with a Low "impact" and Low "likelihood" will have the lowest risk score (green shaded region of the portfolio risk matrix).

After identifying an investment need, ComEd identifies possible risks and weaknesses for each potential investment. ComEd performs this self-critical assessment by encouraging our employees to be the toughest critics of our own work to promptly and appropriately discover and address problems or adopt better methods or practices. This approach promotes continuous improvement. Our culture of constructive self-criticism is one way in which ComEd prudently manages its business.

Process for Investment Review and Approval

ComEd's capital management policies outline the processes for securing approvals, valuation, reporting, control, and record keeping. In addition, ComEd has control processes requiring final authorization and challenges prior to undertaking a project or program and then ongoing monitoring of budget and performance metrics for all approved projects or programs of work. The policy requires approval at the ComEd Director/Vice President level or above for most major expenditures. Projects with progressively higher costs require progressively higher levels of formal review and approval by ComEd officers, executives, or board committees.

As ComEd develops projects and programs, they will go through challenge processes to ensure technical justification, business benefit, the efficiency of planning and execution, and the incorporation of lessons learned from previous similar projects. These challenges, which are consistent with ComEd and industry standards, require that projects conform to good utility practice and ComEd standards based on best practices. While ComEd measures all investments to keep costs down, major investments are subject to a vigorous and formal challenge process that ensures fully informed decision-making, particularly with respect to refining the scope of various investment proposals and challenging cost projections.

Appendix B – Representative ComEd Standards and Procedures – contains documentation and procedures outlining the planning process.

2.3 Planning Process Details and Prior Investment Examples

The figure below provides a simplified representation of the grid to illustrate where the six categories of capital investment are made:

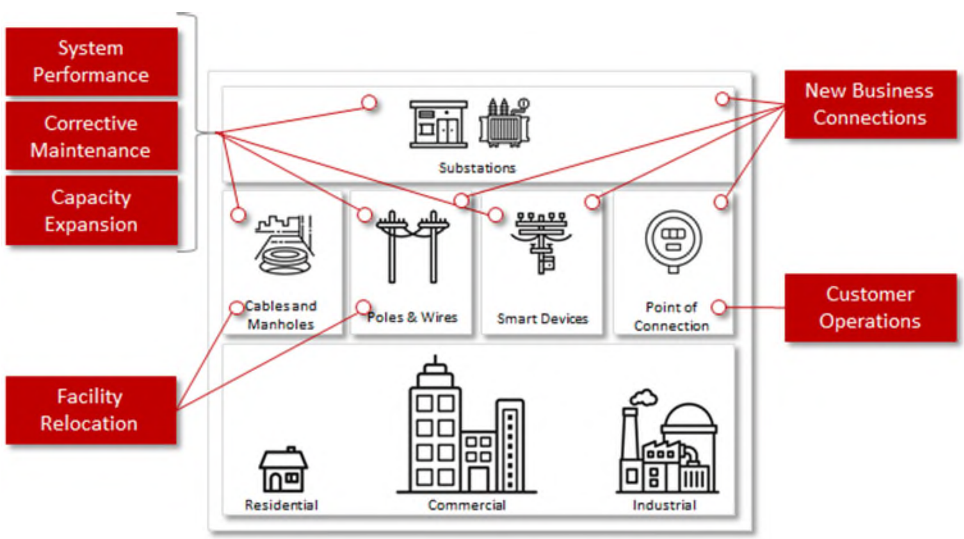


Figure 2-3. Simplified Grid Representation[10]

[10] Figure 2-3 excludes necessary supporting investments in areas such as vehicle purchases, real estate and facilities, tools, and IT projects.

2.3.1 System Performance

Investments in this category focus on the safe and reliable performance of the electric system and are sub-divided into four areas:

- **Substation:** Investments to maintain and improve reliability, resilience, physical substation security, reduce fire-related risk, and comply with Environmental Protection Agency (EPA) regulations. Investments include proactively replacing poor performing or obsolete substation equipment (such as transformers, circuit breakers, and switches), as well as physical security systems (such as anti-cut and anti-climb fences, remote monitoring equipment, fire detection and suppression systems), and transformer secondary oil containment pits.

  - Equipment replacements at substations include transformers, breakers, circuit switchers, capacitor banks, voltage transformers, bushings, insulators, surge arrestors, conductors, and disconnects. Replacements are typically based on historical review of substation lockouts (i.e., review of quantity of lockouts, number of repeat operations, number of customers impacted, critical customers) along with the material condition of equipment (i.e., monitoring equipment readings, obsolescence, age) to ensure reliable operation of the electric system.

  - Substation resilience is addressed through flood walls, sump pump replacement, roof/building repairs/replacements, ground grid repairs, and improving drainage; each of which is identified during programmatic maintenance and/or proactive engineering studies. Resilience is also considered in the design of the configuration of substations. Resilient design includes replacing outdoor buses with busses that are housed in indoor switchgear buildings and replacing a straight bus with a ring bus, which provides additional protection against external factors. Other resilient design enhancements allow for the ability to switch substation equipment to perform maintenance and repairs while minimizing the impact of abnormal configuration.

- **Protection and Control**: Investments to maintain, improve and modernize the reliability, resiliency, and security of the equipment responsible for the protection, control, and safety of the system. These investments eliminate legacy and obsolete relay and Supervisory Control and Data Acquisition (SCADA) system equipment and replace them with microprocessor-based protection relays and modern SCADA equipment providing remote monitoring and data analytics capabilities.

  Investing in advanced microprocessor-based relays enables faster tripping protective schemes and remote monitoring capabilities. In conjunction with the SCADA-enabled real-time analog data readings capabilities and enhanced Communication Channels, Protection and Control investments prevent momentary outages, allow for real-time monitoring, minimize the extent of fault damage, and streamline restoration efforts to shorten outage duration times.

- **Transmission - High Voltage Distribution (HVD):** 69 kV and 138 kV HVD investments are focused on increasing reliability and improving overall system resiliency through proactive equipment replacement, line rebuilds, and reconductoring projects on the HVD system. Typical investments occur across programs, including wood-to-steel structure replacement, cable, joint, casing, and termination replacement, and insulating equipment upgrades.

  - Equipment replacements for overhead HVD include wood pole to steel structures, wood cross-arms, and installation of cascading mitigation structures that increase reliability and resiliency on the HVD system and mitigate damage to HVD structures during severe weather events.

- Equipment replacements for underground HVD include pressurizing plant units, cable, joints and joint casings, and terminations that increase the reliability of the HVD system.

- **Distribution**: These investments are designed to execute long-term electric safety and reliability initiatives through the upgrade and replacement of poor performing or obsolete infrastructure and the addition of distribution system improvements to meet customer needs, regulatory requirements, and necessary resiliency improvements. Typical investments include the installation of Distribution Automation (DA) and monitoring equipment and the associated communication infrastructure that supports necessary resilient system visibility and operation, cable replacement, overhead and underground equipment upgrade and replacement, distribution system asset upgrades, and circuit reconfigurations to maintain and improve customer reliability and operational flexibility as well as underperforming circuits and "pocket" areas of the system. The assets on the distribution system must be maintained for system health, safety, and reliability, and the design must be brought to the new requirements of the grid to facilitate safe bidirectional power flow that keeps DER online across more extreme weather.

    - ComEd performs the planning process for this group of distribution investments on a continuous basis and refines the process annually in the LRP process. These programs are outlined in the Distribution Reliability Improvement Programs procedure, provided in Appendix B. In summary, ComEd refines programs through cross-functional technical challenges for each investment, informed by system plant performance to achieve reliability, resiliency, and power quality objectives for all customers. To accomplish this, ComEd continuously reviews the system for reliability and resiliency by cause. Causes include, but are not limited to, overhead mainline events, underground mainline events, overhead fused section events, and underground fused section events. The distribution of events and respective impacts to customers inform how ComEd adjusts and prioritizes the investment programs.

    - ComEd designs and manages each program to target specific safety, reliability, or resiliency by cause items. If there are specific trends that emerge or asset conditions that evolve, ComEd reviews program investments to calibrate their impacts and adjust planning to target desired impact levels.

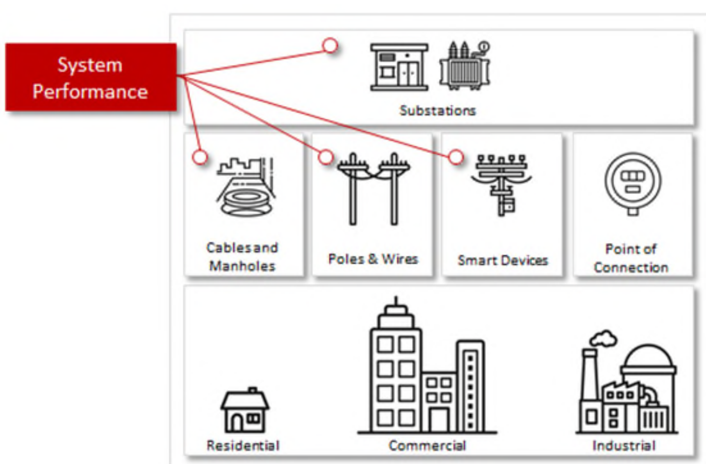


Figure 2-4. System Performance Investments

Sample System Performance Programs – Since 2012

- The **DA** program has installed approximately 7,400 devices on the distribution system in total through 2020, including more than 4,600 DA devices since 2012, to better "sectionalize" parts of the grid and thereby minimize the number of customers who experience a sustained interruption when an event occurs on the system. The DA devices provide visibility and operational flexibility to the system. They detect system issues and automate feeder switching – effectively re-routing power around a fault location. The DA program has effectively avoided 12 million customer interruptions since 2012.

- The **Substation Hardening** program focuses on the modernization of substations, upgrading electro-mechanical protective relays, replacement of aging circuit breakers, enablement of two-way communications between the control center and substations, and installation of technology to monitor transformers remotely. This results in improved fault detection, remote asset monitoring, and site security. ComEd has modernized 15 substations since 2012.

- The **Storm Hardening and Distribution System Resiliency** programs improve the resiliency of the system to storm-related damage and reduce the number of customers with repeat power interruptions or long duration interruptions. The programs do this by deploying various engineered solutions on circuits including overhead-to-underground conversion, installation of tree-resistant conductors or Hendrix Spacer Cable, and re-rerouting of circuits. As a result of the programs and other investments, since 2012, ComEd has reduced the total customer interruption (CI) during storms by 34%, and the number of customers experiencing multiple power interruptions in a year by more than 70%.

- The **Underground Residential Development (URD) Cable Replacement** program addressed underground cable faults that historically were a major driver for customers with repeat power interruptions. ComEd has remediated nearly 6,100 miles (70%) of the 8,700 miles of problematic bare concentric neutral cable. This has reduced annual cable system faults by 57% and avoided 1.5 million customer interruptions since 2012. Furthermore, the program has avoided an estimated 61,000 cumulative faults and $128 million in O&M costs.

- Prior to 2012, the main driver for the City of Chicago's System Average Interruption Frequency Index (SAIFI) was mainline underground cable system failures. ComEd has replaced almost 900 miles of primarily lead cable with approximately 3,000 miles of lead cable remaining in service. Approximately 5,000 lead cable defects were identified during manhole assessments as part of the **Mainline Cable Replacement** program. Compared to 2012, there were 300 fewer mainline cable annual faults in 2020 – a 43% decrease.

- The **Ridgeland 69 kV Cable Replacement** program replaced more than 10 miles of high voltage underground cable, including joint casings and corrosion control systems. The Ridgeland Substation is a 138 kV to 69 kV "feed-through" substation providing the 69 kV network "feed" to five substations serving approximately 50,000 customers. The program improved the resiliency of the system and the substations serving this system and reduced the risk of a significant event.

- The **Substation Proactive Replacements** program replaced over 1,200 pieces of substation equipment based on material condition, including transformers, breakers, and capacitor banks. Outage history, material condition, and design elements are used to identify equipment at the greatest risk of failure to prioritize work throughout the service territory in this ongoing program. The benefit of this work includes improving the resiliency of the substation system and reducing the risk of large-scale events, decreasing the risk of loss of major power flows during peak times, replacing obsolete equipment, and increasing security.

- The **Distribution System Modernization** program focused on enhancements in safety, operability, and reliability by addressing obsolete equipment and improving system design. The program consists of: replacement of live front transformers, sectionalizing switches, and 4 kV switching tables; and more than 600 completed line-clearance projects, replaced automatic throw-over (ATO) switches, 34 kV pole top switches, and 4 kV oil-filled terminations.

- The **Substation Programmatic** work reduced the risk of large-scale substation events through projects aimed at minimizing impacts from flooding, enhancing grounding systems to improve lightning protection, installing wildlife protection, and addressing substation building structural concerns. In 2020, substation flood mitigation investments protected vital infrastructure during the region's second wettest spring on record since 1871.

Figure 2-5. Example of Effective Flood Mitigation at a ComEd Substation

2.3.2 Corrective Maintenance

ComEd sub-divides investments in this category into three areas:

- **Distribution**: Investments to repair or replace electric distribution system material and equipment that has been damaged, deteriorated, or failed, and to remediate voltage and clearance concerns identified through our inspection programs. Typical spending involves investment in poles, transformers, switches, wire, cable, and miscellaneous materials and distribution equipment. The corrective maintenance distribution investment plan is built on a few key components.

    - Storm costs are planned and updated annually based on reviewing the prior 3 years' storm restoration and replacement costs, recognizing and correcting for statistical outliers, and projecting storm repair costs for future years.

    - Programmatic replacements and repairs are determined through preventative maintenance inspections, as well as during system operation, and are all screened and prioritized in accordance with criteria based on the asset involved and safety and reliability risk for the observed condition. The screening and prioritization of most corrective maintenance upgrades and repairs are governed by a work management process. In sum, all corrective maintenance work is screened and assigned a priority starting with emergent – priority 10 (for these highest priority items, crews will work around the clock until the issue is corrected) – through priority 40 (these target completion within the predominant maintenance cycle for the respective equipment). The programmatic replacements and repairs include core system maintenance activity like damaged and broken cross-arms, insulators, arresters, switches, and guy wires on the overhead system, and damaged or missing cable supports, bonds and grounds, manhole frames, and covers on the underground system. This work is first bundled wherever possible for efficiency along with other designed system work in the System Performance and Capacity Expansion categories. The remaining investments are planned based on historical volume trends by priority and type. The execution efficiency is continuously challenged for improvement by planning to be equal to or better than the best of the prior 3 years' performance.

  - Other examples of programs in this investment group include wood pole replacements and "c-truss" pole restorations, which are prioritized based on the remaining ground line strength of the structures and facilities served in order to address top safety and reliability health impacts first, consistent with NESC requirements. Another example is vault roof replacements. Structural inspections determine the health score of the distribution vault roofs, and those with the highest risk scores are prioritized for replacement.

  - Core repair and operation programs include elements such as: 1) repair of cable faults; 2) emergent replacement; 3) repair of assets due to vehicle hits, dig-ins, and failures; 4) repair and replacements of streetlights; 5) location and marking of facilities; 6) investigating customer complaints; and 7) operating and switching the system. The investments for these programs are planned based on trending volumes from prior years' activities, adjusted for any planned system performance program impacts, and planned to execute at an efficiency level equal to or better than the best of the prior 3 years' performance.

- **Substation**: Emergent investments to repair or replace substation material and equipment as it fails. Equipment repaired or replaced includes substation transformers, capacitors, relays, SCADA, circuit breakers, substation storm water management, substation facilities, and substation fences. The annual budget is based on historical investment and factoring in equipment material conditions.

- **Transmission – HVD**: Emergent investments to repair or replace overhead and underground HVD material and equipment as it fails to restore the HVD system and provide continuous reliability to our customers. Investments include repairing or replacing cable, joints and terminations, pipe coating repairs, wood structure components, corrosion, and cathodic protection systems. The annual budget is based on historical investment and factoring in equipment material condition.

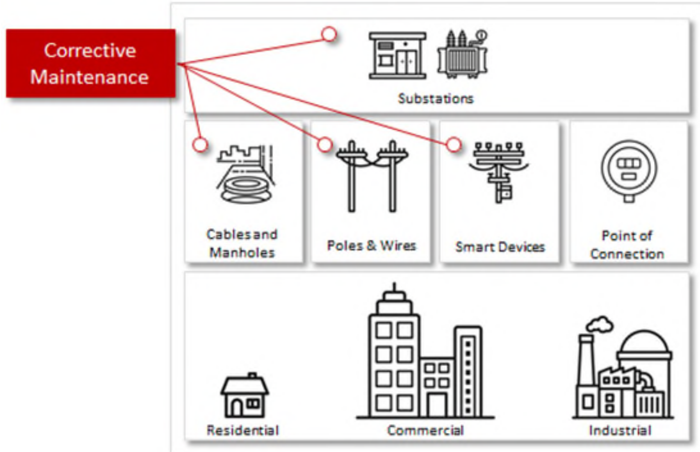


Figure 2-6. Corrective Maintenance Investments

<u>Sample Corrective Maintenance program</u>

ComEd inspects and treats its distribution wood poles on the industry-standard 10-year cycle. Since 2012, ComEd has completed the inspection and treatment of almost 1.2 million wood poles as well as the replacement or reinforcement of over 45,000 wood poles, significantly improving the resiliency of the grid.

2.3.3 Capacity Expansion

Planning the distribution grid is a continuous annual process. A centralized group of engineers – the Distribution Capacity Planning group – performs the capacity planning process for the distribution system in consultation with several other ComEd groups.

The annual capacity planning process entails granular component analysis to provide a bottom-up and top-down forecast of more than 8,600 components consisting of distribution substations, substation transformers, and distribution lines and feeders. These components are found across ComEd's service territory, which includes both cities and rural areas. This analysis is necessary because each feeder is unique, with its own number and type of customers. Customer examples include, but are not limited to: 1) residential customers whose load peaks during the summer with intensive use of air conditioning; 2) data centers whose load can remain largely constant throughout the year; and 3) agricultural facilities whose load rises and falls with the farming seasons.

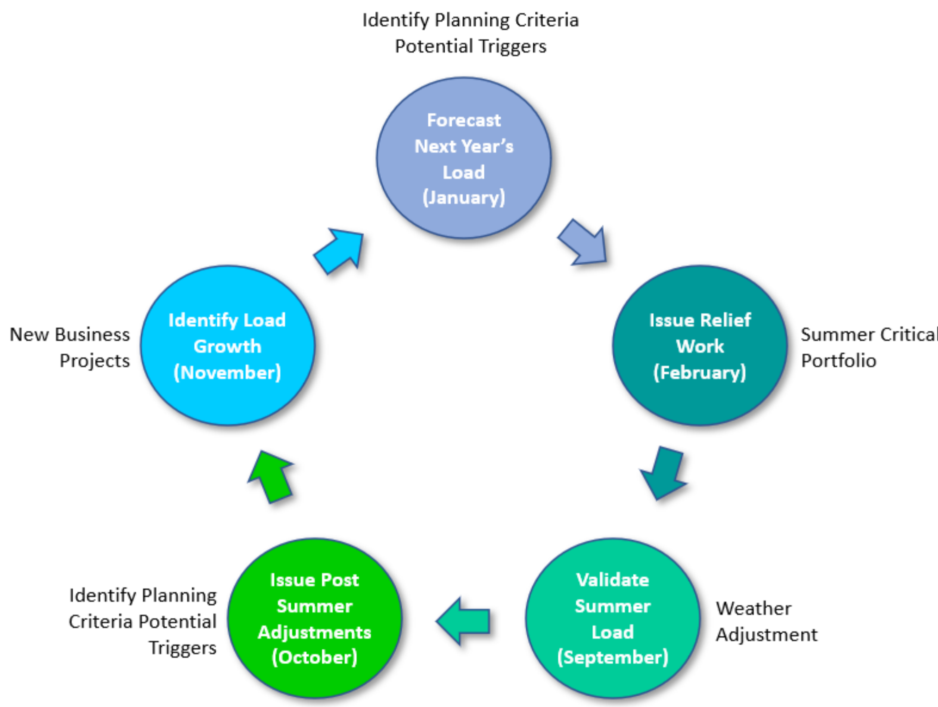


Figure 2-7. ComEd's Annual Distribution Capacity Planning Process

The annual Distribution Capacity Planning process begins with validating the individual, actual peak loads on distribution feeders and substations across the grid. This process leverages SCADA data observed from each individual component on the system to identify the recent peak loads. This process is foundational to building equipment load forecasts to ensure the distribution grid is built to provide safe and reliable service to customers under reasonably expected peak load conditions. Throughout most of North America, the peak load occurs on hot summer days due to air conditioning load being the highest at these times. The peak load is thus temperature sensitive, and even without any changes to the number of customers, the peak would vary year to year, as the summer temperature varies with actual weather. This load sensitivity to temperature is observed and calculated and used to adjust past year's actual peak loads to a temperature baseline. Currently, the temperature baseline is selected by looking at the daily peak temperatures during the cooling season for previous years (up to 30 years). A baseline peak temperature is calculated such that 90% of the daily peaks are below it and 10% above it. This is the 90th percentile daily peak temperature. The relation of peak load to temperature is then used to "adjust" the past years' daily peak loads to what they would have been had the peak temperature been at that baseline value. This is commonly called "90/10 adjustment." Trending and statistical analysis can then be applied to the 90/10 adjusted peak loads to forecast what the load will be in the coming years if the peak temperature is at that baseline value. To this forecasted peak load, at the baseline temperature, new loads due to planned new construction can be added. Distribution system capacity is planned to ensure it is adequate for loading at infrequent but realistic extreme hot or cold weather conditions. Loads may be slightly higher for weather conditions more extreme than design levels but should not result in significant equipment thermal loss of life or an increase in equipment failure rates. Design summer peak weather is defined to be at the 90th percentile of maximum annual weekday values measured in cooling degree days.

This is an industry best practice adopted by ComEd in 2000. Cooling degree days are a measure of the operating level of air conditioning and other cooling equipment on a hot weather day. It is defined as the average of the daily minimum and maximum Fahrenheit degree temperature, after subtracting 65 from the average.[11] Analysis of several weather measurements demonstrated that cooling degrees provide the best correlation of load to weather for a single weather variable. Cooling degree days are measures of the operational level of air conditioners and other cooling equipment on hot weather days. Without this detailed analysis of load and temperature, high summer temperatures could lead to disruptive events where insufficient capacity to meet load results in customer outages.

Though most of the system is summer-peaking, there are typically a small number of winter-peaking feeders. Several of these feeders, for example, serve high rise buildings in downtown Chicago that utilize electric heat. Similar processes of both validation and weather adjustment are also done for these winter-peaking feeders. Here, feeders are evaluated at the 90th percentile of heating degree days. Heating degree days are a measure of the operating level of heat and other heating equipment on a cold-weather day. It is defined as 65 minus the average of the daily minimum and maximum Fahrenheit degree temperature. Analysis of several weather measurements demonstrated that heating degree days provide the best correlation of load to weather for a single weather variable. ComEd uses this alternate calculation method of utilizing the mean daily hourly temperature instead of the average of the high and low for this process. There are also a few feeders on the system that peak during seasons other than summer or winter due to unique customer characteristics, including hosting special events or being closely related to the agricultural industry. These feeders also require peak load validation and forecasting.

ComEd's Distribution Capacity Planning process considers the types of load, recognizing that different types of customers respond differently to changing weather conditions. For example, residential customers' load is more responsive to hotter weather than industrial customers' because air- conditioning can be such a large portion of a residential customer's peak load. As a result, because each feeder has a different mix of residential, commercial, and industrial customers, ComEd develops and applies individual weather adjustments to reflect each unique mix. As part of the validation process, ComEd considers equipment configuration, such as planned and emergent switching, when determining actual peak load to ensure the forecast is built to the normal configuration. As part of the equipment configuration evaluation, ComEd also considers any ATO and customer-switching. Additionally, ComEd considers DER, such as customer-owned distributed generation interconnected to the distribution system, as well as called load curtailment events.

After ComEd validates feeder and substation loads, ComEd reviews and adds local load growth and new business projects to weather-adjusted validated peak loads to build the forecasts. This process includes considering regional economic trends to forecast localized growth, as well as local projects, including new residential, commercial, and industrial construction and/or expansion to existing facilities that increase the peak load. ComEd also considers beneficial electrification, through the forecasted deployment of charging facilities in specific locations, as well as regional load growth with increased adoption of technologies, such as electric vehicles. The planning horizon is 2 years for feeders and 5 years for distribution substations.

[11] National Weather Services – Heating and Cooling Degrees - https://www.weather.gov/

ComEd then reviews components (feeder, transformer, and terminal) to determine whether they comply with planning guidelines, including whether there is sufficient capacity and whether contingency requirements are being met. ComEd evaluates each component according to its allowable rating, which refers to the maximum permitted equipment loading during normal configuration, sufficient to meet the range of normal peak demands for the 90/10 baseline peak temperature. This rating represents the maximum loading during normal configuration that will not exceed load to trip limits, applicable emergency ratings, or voltage limits considering the effect of automatic load transfers from ATO switching and planned outages of applicable DER. ComEd plans feeders with tie feeders (i.e., adjacent feeders that can be interconnected via installed switches), such that the load of the circuit can be transferred in the event of a loss of the main source of the feeder. ComEd incorporates this capacity for contingencies for tie feeders into the allowable rating. In addition, ComEd considers area congestion. The ComEd distribution system is currently divided into 51 planning areas, with each consisting of 2-6 adjacent substations typically bounded by rivers, interstate highways, or other barriers to feeder routes. Area loading should be limited to 95-98% of capacity to allow for unplanned outages and customer load additions. ComEd plans high-voltage distribution substations such that loading will not exceed the rating of the remaining transformers with the largest transformer out of service. ComEd implements changes that have been made to the planning criteria as part of the Area Plan process as not all components may meet current criteria.

The allowable ratings for key components are calculated as follows:

- **Distribution Substations** are planned to be loaded at no more than 100% of the normal capacity for the annual projected load. Multi-transformer substations are typically planned for the first contingency operation (N-1). The loss of a transformer or supply line for a multi-transformer high-voltage substation may result in a momentary interruption while the load is automatically transferred to the remaining line(s) or transformers(s). The N-1 scenario is the loss of the largest station transformer. Relief may require up to 10% of the allowable rating to be transferred to adjacent stations. For substations where a high level of vulnerability of overlapping transformer outages resulting from transmission line failure(s) exists due to system configuration, ComEd applies a second contingency (N-2) criteria. N-2 represents a condition under which two elements (lines or transformers) are out of service. This typically applies to stations in the City of Chicago Central Business District (CBD). For single transformer substations, the scenario is somewhat different. Here, the outage of the transformer or supply line to a single transformer substation may result in an interruption in service of up to 2-hours since 100% of the substation’s load must be transferred to adjacent distribution circuits fed by other substations.

- **Distribution Lines, Feeders, and Circuits:** ComEd’s feeder design criteria ensure timely restoration of service via automated or manual distribution switching. Distribution feeders are planned to be loaded at no more than 100% of the normal capacity for the annual projected load. Distribution circuits are to be planned with a minimum of two ties to other distribution circuits so that the ultimate peak load of the circuit can be transferred in the event of the failure of the main source of the circuit. This planned loading level for circuits preserves reserve capacity on circuits (i.e., unused capacity during normal conditions) that can be used to carry the load of adjacent feeders during first contingency N-1 conditions. Such planning facilitates DA loop schemes.

The Distribution Capacity Planning group leverages tools that enable engineers to examine and analyze different types of data, develop projects that could address challenges, conduct analysis to predict the effects of proposed system modifications, and track the progress of approved projects. As discussed earlier, the planning process requires the examination and consideration of data, including actual load on different feeders, existing system configuration, new construction, and expansion to facilities, as well as evaluating overloads or voltage problems. Tools such as the Area Planning Tool (APT), the Consolidated Estimating Tool (CET), the ComEd Geographic Information System (CEGIS), the Outage Management System (OMS), and PI-Historian are used for this process. ComEd develops proposed solutions as well as predicts the effects of these system modifications, utilizing tools including AutoCAD, Network Manager or Ranger/SCADA, and CYMDIST. After the approval of projects, tools including Asset Suite and the Customer Information and Management System (CIMS) are leveraged to ensure that system modifications are installed as planned.

ComEd integrates validated forecasts into an area plan that is developed for each portion of ComEd's distribution grid. Area plans cover system elements, including: 1) high-voltage distribution substations supplied by 69 and 138 kV lines, 2) medium-voltage distribution substations supplied by 15 and 35 kV class circuits, and 3) distribution circuits (5, 15, and 35 kV class equipment). Planners develop and evaluate multiple solutions within each area to address the components that exceed ComEd guidelines, considering the cost (initial, as well as long-term), pre- and post-project risk scores for the preferred solution, and the consequence analysis of each potential option. For the development of solutions, other groups, including New Business, Regional Engineering, and Distribution Operations, contribute their perspectives. As part of this process, planners review the substation health index report to determine the material condition of any components that would be relieved as well as those that could play a part in the solution, to see whether one of the potential solutions meets not only the capacity needs but also improves a material condition concern. Typical solutions include, but are not limited to, transformer additions, DA, new feeders, feeder extensions, feeder switching, phase balancing, and capacitor installations.

Peers, managers, and other teams with relevant perspectives then challenge to ensure that planning guidelines are followed. As part of this challenge, the plan and associated project diagrams are reviewed for technical and economic justification to ensure that the most appropriate solution has been chosen.

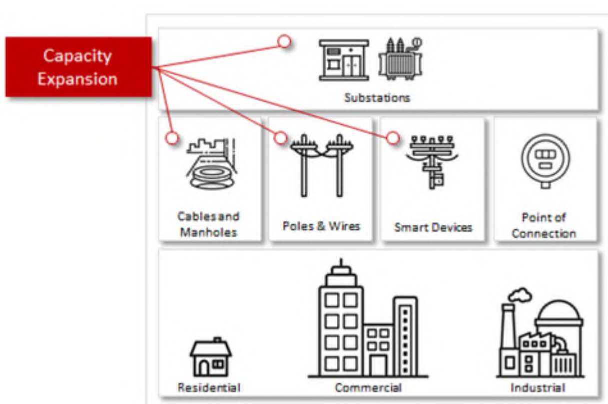


Figure 2-8. Capacity Expansion Investments

<u>Sample Capacity Expansion Programs</u>

- **Summer Critical:** The Summer Critical program includes investments to support load growth while assuring that ComEd operates a safe and reliable electric distribution system. Work performed in this area is driven by load forecasts for all feeders and substations to identify where any capacity additions or reconfigurations are needed to meet system planning criteria. As potential system planning violations are identified, ComEd develops solutions to address the capacity shortages. Potential solutions can range from feeder extensions, feeder switching, capacitor installations, DA, transformer additions, and new feeders to new substation builds. In selecting a solution, ComEd considers several relevant factors, which may include cost, safety, material condition, and operational flexibility. ComEd also looks to deliver innovative solutions, including non-wires alternatives (NWA), such as energy storage for customers.

- **Voltage Conversions (4 to 12 kV):** The 4 kV to 12 kV Conversion program targets some of the oldest and potentially obsolete equipment on the system. There are approximately 1,100 4 kV feeders on the ComEd system. Strategic conversion of 4 kV to 12 kV will provide the benefit of increased operational flexibility and hosting capacity, which could be especially significant with the increased penetration of DER and electrification. The increased operational flexibility that this project provides can also enable greater levels of reliability. Upgrading to 12 kV provides a greater number of switching options with adjacent feeders, which allows for faster restore times from outages and more flexibility for maintenance. The conversions will further enhance reliability by allowing the addition of DA devices as well as increased fusing and sectionalizing. The 4 kV to 12 kV feeder conversions enables ComEd to retire 4 kV transformers which are aging and/or obsolete equipment.

- **Voltage Optimization (VO):** ComEd initiated its VO program through Illinois' Future Energy Jobs Act (FEJA) to provide environmental benefits to ComEd's service territory. The primary goal of the VO program is to achieve energy efficiency through achieving up to 2-3% reductions in annual energy consumption. The energy savings are accomplished using voltage regulating equipment, including load tap changers (LTC), volage regulators and capacitor banks to flatten the voltage profile throughout the feeder and reduce service voltages. This reduction allows customers with voltage-sensitive loads to consume less energy, enabling cost reductions and more sustainable energy use. ComEd's VO program involves approximately 460 substations, which will all be activated by the end of 2026. By the end of the program's third year in 2020, VO had been activated on 143 stations, resulting in more than 466,000 MWh of annual energy savings. The entire program is expected to provide more than 1,600,000 MWh of annual energy savings that result in carbon dioxide (CO_2) emissions reductions of more than 3.2 million metric tons annually.

- **Bus Reconfiguration:** The configuration of buses on substations can have a large impact on the reliability and resilience for the end customers. Some legacy bus configurations on the ComEd system were designed in a fashion that do not lend themselves to be easily or automatically switched after a disturbance, leading to outages longer than otherwise necessary. The Bus Reconfiguration program entails the implementation of more robust configurations that can be automatically reconfigured. Specifically, the distribution substation bus program targets high customer count substations with single points of failure that could lead to reduced reliability.

2.3.4 Customer Operations

Investments in this category include new electric meters when reactive or planned meter work results in the removal or replacement of meter assets. It also includes costs associated with the termination/abandonment of electric service where there has not been an active customer for an extended period and the meter or valve is not accessible, resulting in the need to remove the service and abandon the meter.

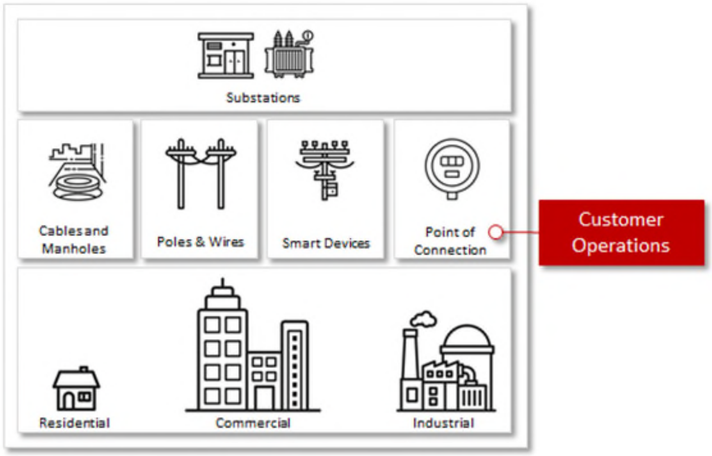


Figure 2-9. Customer Operations Investments

Sample Customer Operations Programs

The **Smart Meter** program resulted in 4.2 million legacy meters being exchanged for AMI meters. Along with smart meters, the AMI deployment also included communications network equipment, which allows for two-way communication between the utility and the customer and supports other Smart Grid applications. The ability to remotely verify the status of meters prior to dispatching crews has avoided more than 2.1 million truck rolls since the Energy Infrastructure Modernization Act (EIMA) was enacted. These improvements reduce ComEd's greenhouse gas emissions.

2.3.5 New Business Connections and Facility Relocation

Investments in New Business Connections include those to engineer, design, and install infrastructure to support new electric services to residential, commercial, and industrial customers, as well as support for net meter customer installations. These are customer-driven investments.

Investments in Facility Relocation include those to relocate ComEd overhead and underground primary and secondary electric assets to support Federal, State, County, and Municipal improvement projects. As with the New Business Connections, these are customer-driven investments.

2.3.6 Investments made in Information Technology

It is critical that ComEd's customers are able to contact the company when they have a service disruption, questions about their account, inquiries about how to take advantage of emerging clean energy technologies such as solar and EVs, or are seeking information on how to take advantage of assistance programs for customers with low- and moderate-incomes. These communications rely on a reliable, resilient, and secure technology platform to operate. Projects to support these customer interactions include:

- **Lifecycle projects** – Replace or refresh aging components and mitigate exposure to cyber vulnerabilities; for example, upgrade ComEd's voice communications channels, so they continue to work when public networks fail or are overwhelmed by demand.

- **Operational platform projects** – For example, the Outage Communication project implemented a single system to communicate consistent and timely information about the status of outages in the electric distribution system to internal and external customers.

- **Customer experience projects** – Improve the ease of use of various interactive channels and create tools to provide customers with data and analytics to manage their energy usage, as well as online portals to streamline the process of interconnecting customer-owned DER.

- **Outage restoration projects** – Improve the flow of information within ComEd and leverage analytics to improve performance during high-volume events such as storms.

- **Regulatory projects** – Support the implementation of mandatory projects such as North American Electric Reliability Corporation critical infrastructure protection (NERC CIP) plan requirements designed to secure the assets required for operating North America's bulk electric system and improve reliability and resilience of the system.

2.4 Benefits of Prior Investments and Planning

The investments made as a result of ComEd's planning process have delivered the anticipated reliability benefits with customers experiencing fewer and shorter outages. To illustrate graphically, in August 2020, a powerful derecho storm swept across northern Illinois, bringing hurricane-force winds with gusts higher than 90 miles per hour, extensive lightning, golf ball-sized hail, and 13 confirmed tornadoes. This storm gave ComEd a unique opportunity to gauge the impact and effectiveness of the investments made in the 10 years since a comparable but less ferocious derecho storm struck the service territory in 2010. ComEd restored service to more than half a million customers in less than 24 hours – the fastest time in ComEd history for the recovery from such a widespread outage.

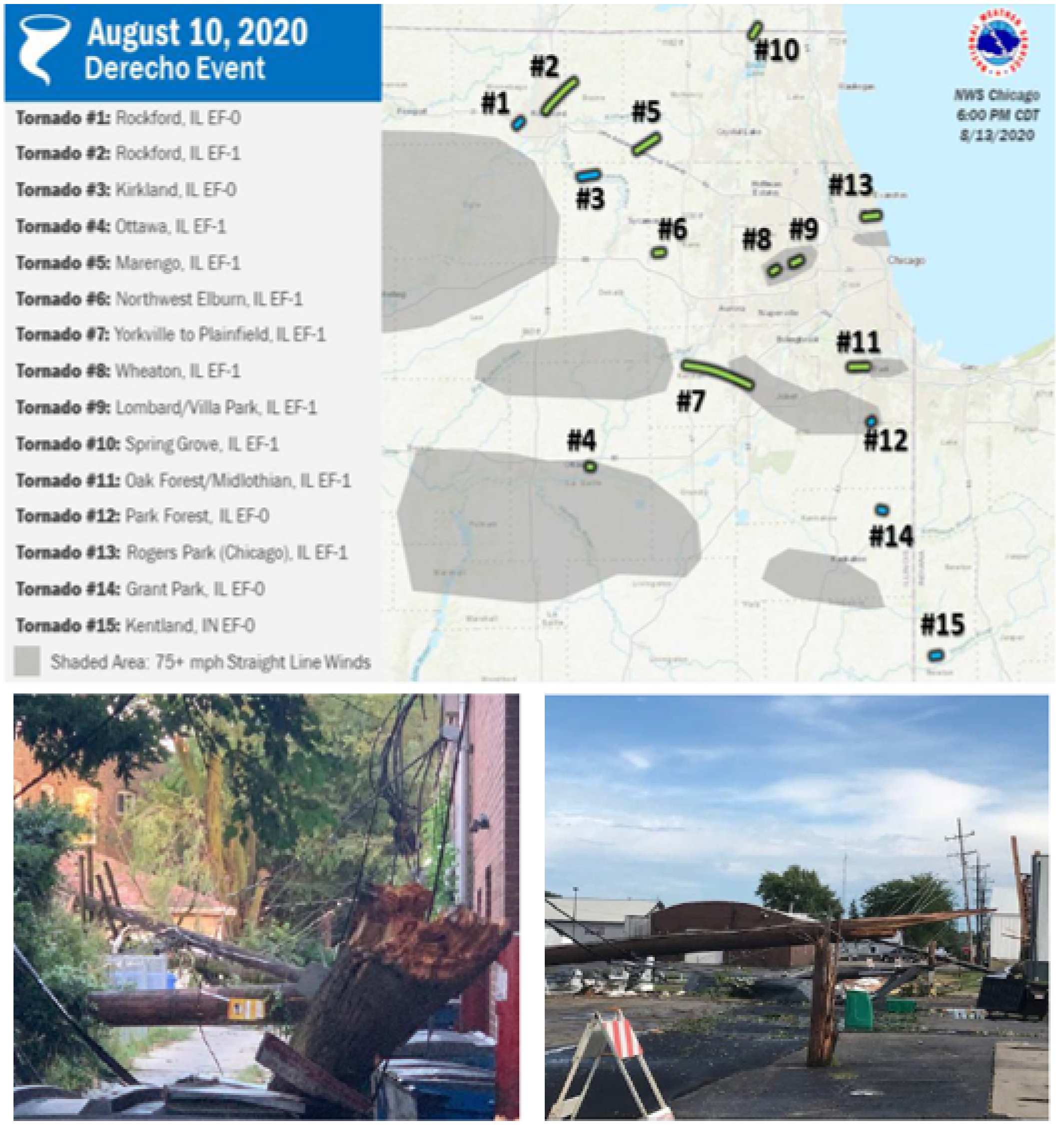


Figure 2-10. 2020 Derecho and Aftermath

ComEd estimates that without the investments made since 2012, an additional 700,000 customers would have been left without power, and that the restoration efforts would have taken twice as long had the investments not been made.

Overall reliability has improved more than 80% compared to the 5-year pre-EIMA average (2007-2011) when the impact of the derecho storm is excluded from the calculations.

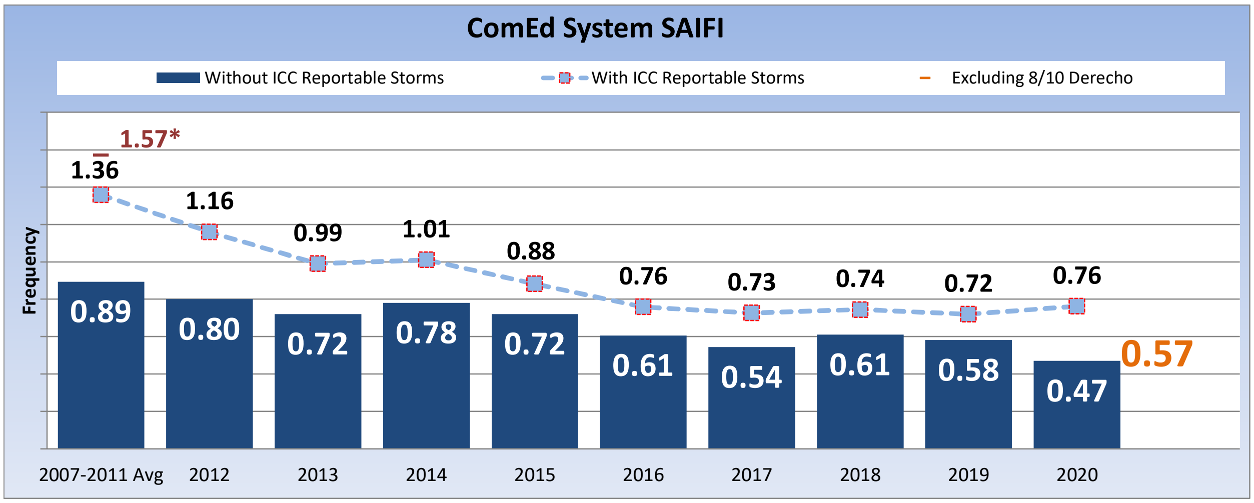
System performance is commonly measured using three metrics:

- **System Average Interruption Frequency Index** (SAIFI) is the average number of interruptions that customers experience. It is calculated by dividing the total number of customer interruptions by the total number of customers served.

- **System Average Interruption Duration Index** (SAIDI) is the average outage duration for each customer served. It is measured in minutes and is calculated by dividing the total duration of all customer interruptions by the total number of customers served.

- **Customer Average Interruption Duration Index** (CAIDI) gives the average outage duration that any given customer would experience (SAIDI/SAIFI) and can be viewed as the average restoration time measured in minutes.

Excluding reportable storms, ComEd's 2020 SAIFI was 0.47 – the first time ever below 0.50. With reportable storms, including the historic derecho, the 2020 SAIFI was 0.76, or 44% improved compared to the 5-year pre-EIMA average.

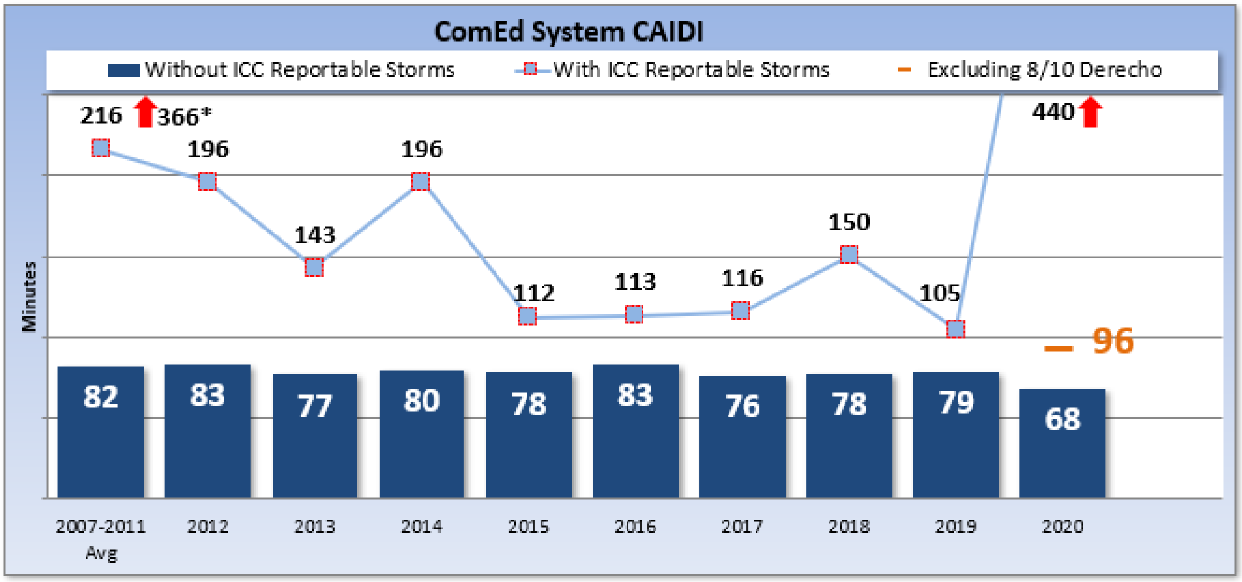


*2011 SAIFI With ICC Reportable Storms

Figure 2-11. System SAIFI

Excluding reportable storms, 2020 CAIDI was 68 minutes – ComEd's best on record and less than 70 minutes for the first time ever. Excluding the impacts of the derecho, overall system-wide CAIDI was 96 minutes – ComEd's best on record and less than 100 minutes for the first time. Including the impacts of all storms and largely driven by the derecho, 2020 CAIDI was unfavorable to 2019 by 335 minutes.

ComEd's continual improvements in SAIFI have significantly improved service for customers and paradoxically challenged CAIDI metrics. This is mainly because: 1) the reduction in large customer outages that generally have faster restoration times increases the average duration of outages that remain, and 2) grid enhancements enable the automatic restoration of many customers, and these split-second outages are not included in CAIDI calculations.



*2011 CAIDI with ICC Reportable Storms

Figure 2-12. System CAIDI

Process improvements, including parallel dispatching, storm process enhancements, and strategic data analytics, continued to have an impact in 2020. The chart above shows CAIDI with and without reportable storms for the past 9 years (since EIMA inception in 2012) compared to the 5-year pre-EIMA average.

ComEd tracks the total number of storms that strike the service territory, which cause higher than average customer interruptions due to inclement weather, thus meeting the storm criteria. Despite an increase in overall storm magnitude, ComEd continues improving on a downward trend compared to pre-EIMA with the help of automatic restorations, storm hardening solutions, and enhanced vegetation management. Without these investments, typically 25% of recent non-reportable storms may have qualified as reportable. The chart below depicts the number of storms, the average customer impact per storm, and the number of customer interruptions per storm outage for the past 9 years (since EIMA inception) compared to the 5-year pre-EIMA average. In 2020, combining reportable and non-reportable storms, the total number of storms has decreased compared to 2019. The average customer impact per storm, excluding the 2020 derecho, reflects a positive trend resulting in fewer customers impacted per storm, yet there was an increase per storm outage. The chart also depicts a decrease in the number of customers impacted due to storm-related outages compared to the 5-year pre-EIMA average. The total customer interruption (CI) during storms has decreased by 34% compared to pre-EIMA and would have been best on record, excluding the derecho, which represents a 70% decrease compared to the pre-EIMA average. The chart also shows avoided customer interruptions (ACI) due to DA during storms.

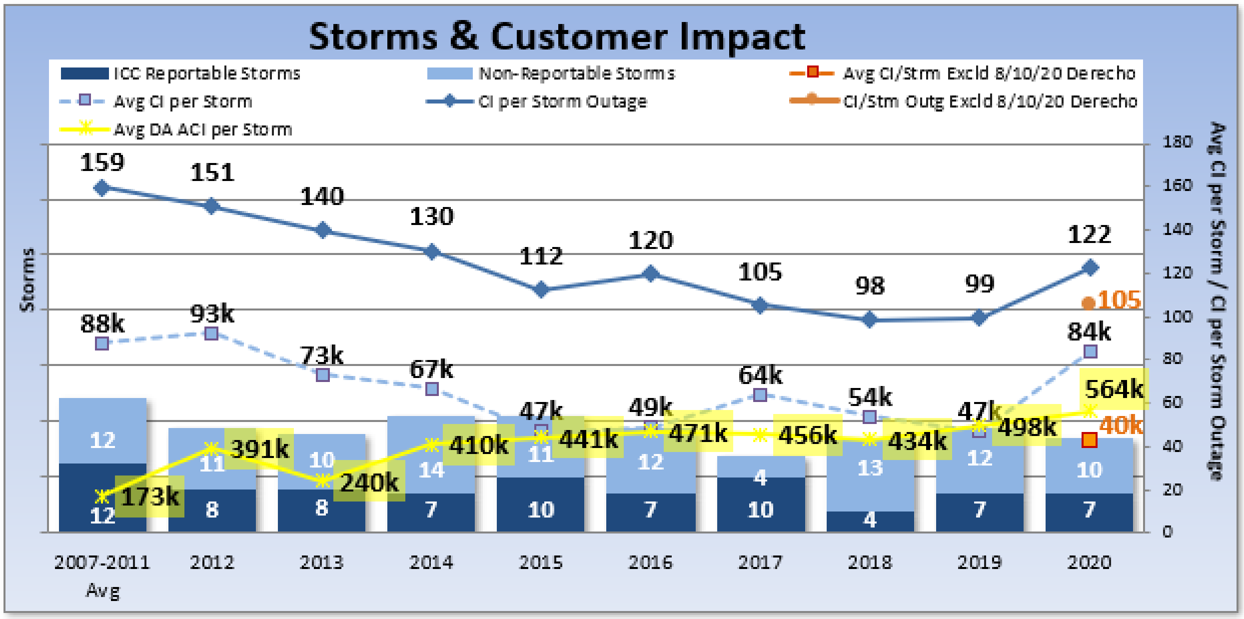


Figure 2-13. Storms and Customer Impact

As illustrated in the preceding charts, the ComEd planning process has enabled targeted investments that have produced quantifiable benefits.

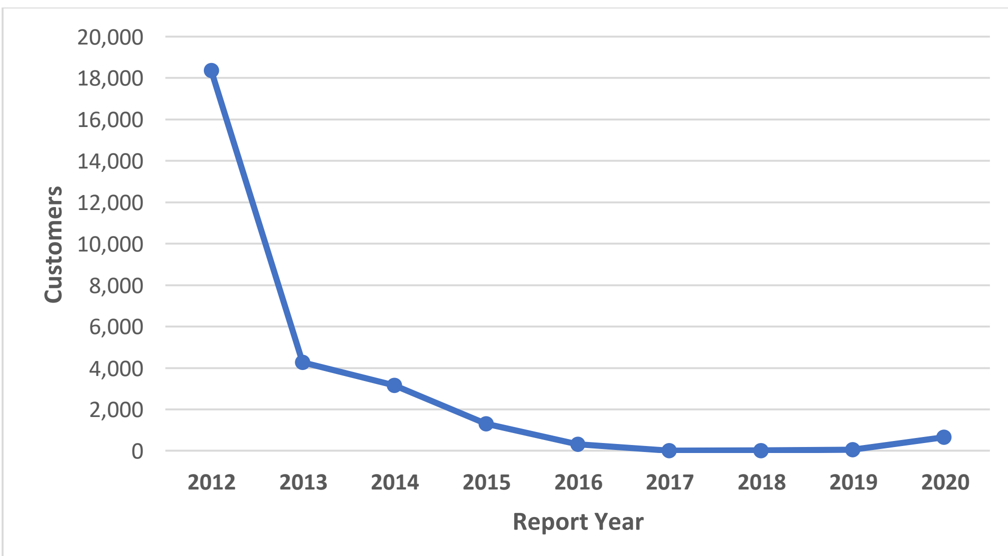


Figure 2-14. Number of Customers Exceeding the Service Reliability Targets (Title 83 Part 411.140)

The chart above illustrates the improvements that ComEd has made since 2012 in reducing the number of customers exceeding the service reliability targets.

The ComEd service territory is divided into four operating areas as depicted below:

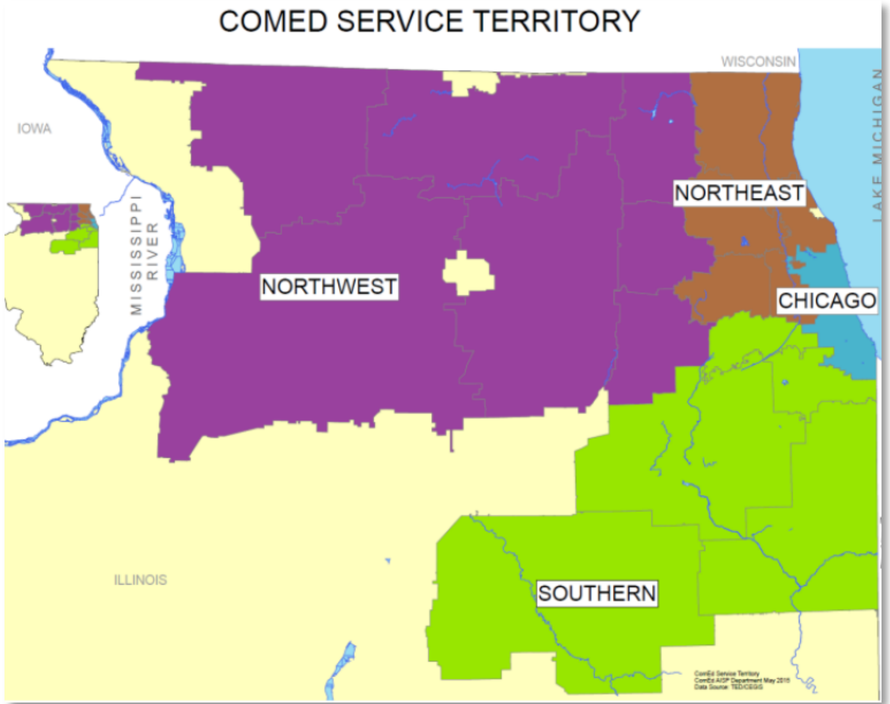


Figure 2-15. ComEd's Operating Regions

The individual performance metrics for each of the operating areas are provided in the figures that follow, providing a more localized view of the system. While there are distinct topology differences between the different regions, all demonstrate the same consistent improvement previously described at the system level when excluding reportable storms.

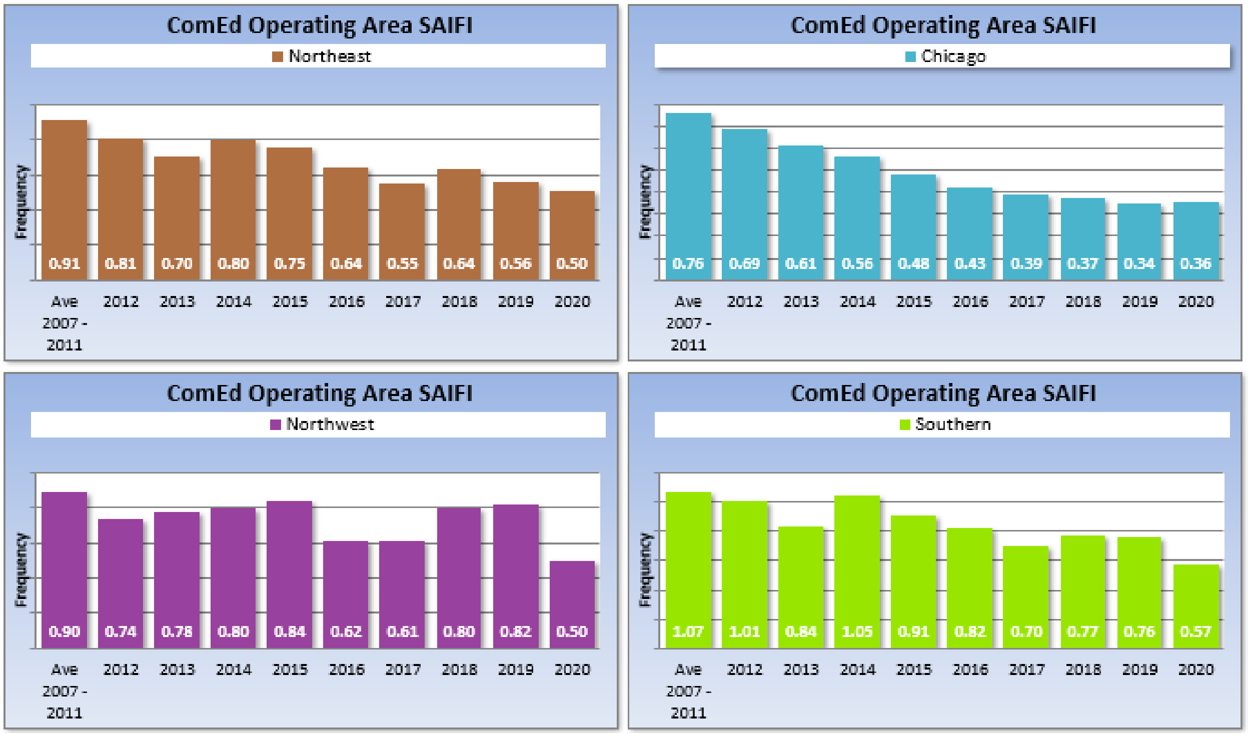


Figure 2-16. Regional System Average Interruption Frequency Index

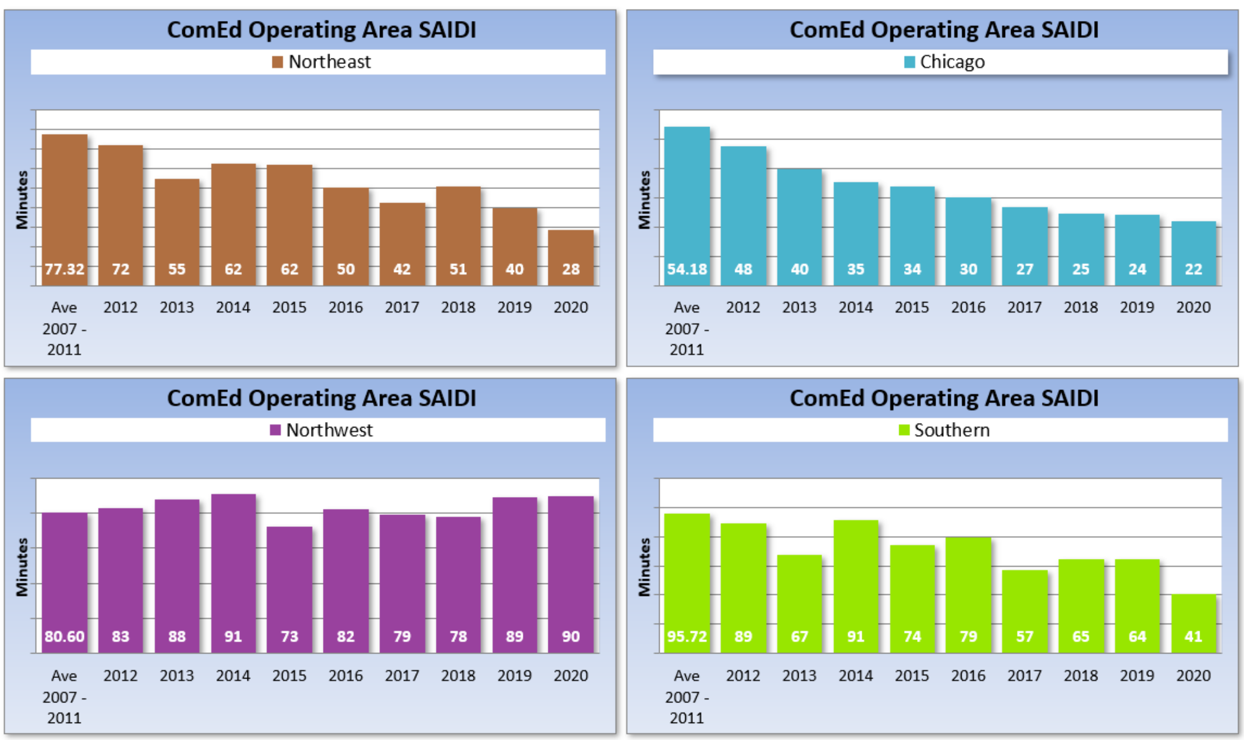


Figure 2-17. Regional System Average Interruption Duration Index

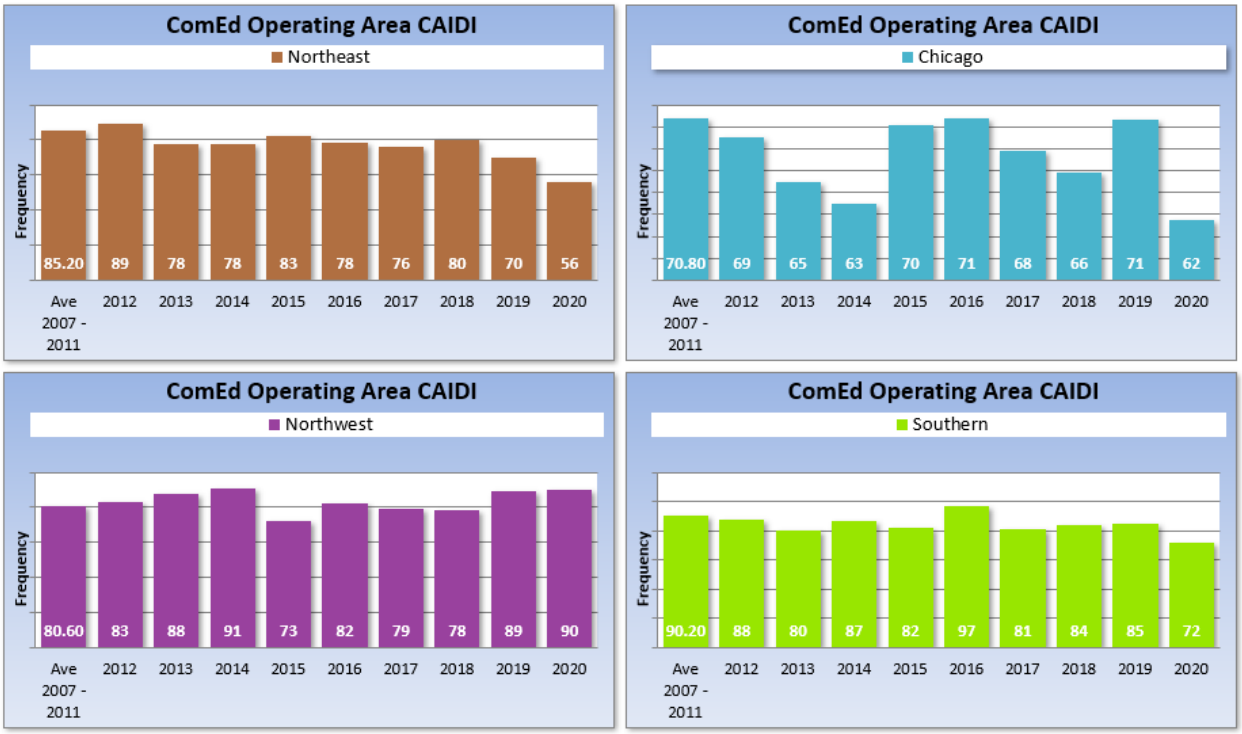


Figure 2-18. Regional Customer Average Interruption Duration Index

We achieved these results by respecting diverse backgrounds and embracing the new ideas that create vibrant communities that drive economic growth. We recognize that when we invest in diverse suppliers, we are touching families, lifting up communities, training the workforce of the future, and creating local jobs. We've increased our spend with diverse businesses year over year. In 2020, our spend with diverse suppliers was nearly 40% of eligible spend.

2.5 **Summary of Distribution System Capital Expenditures**

The graph and table below detail ComEd's distribution grid investments for full year 2017 through 2020 as measured by distribution system and General & Intangible system plant additions that are allocated across both the distribution and transmission rate bases.

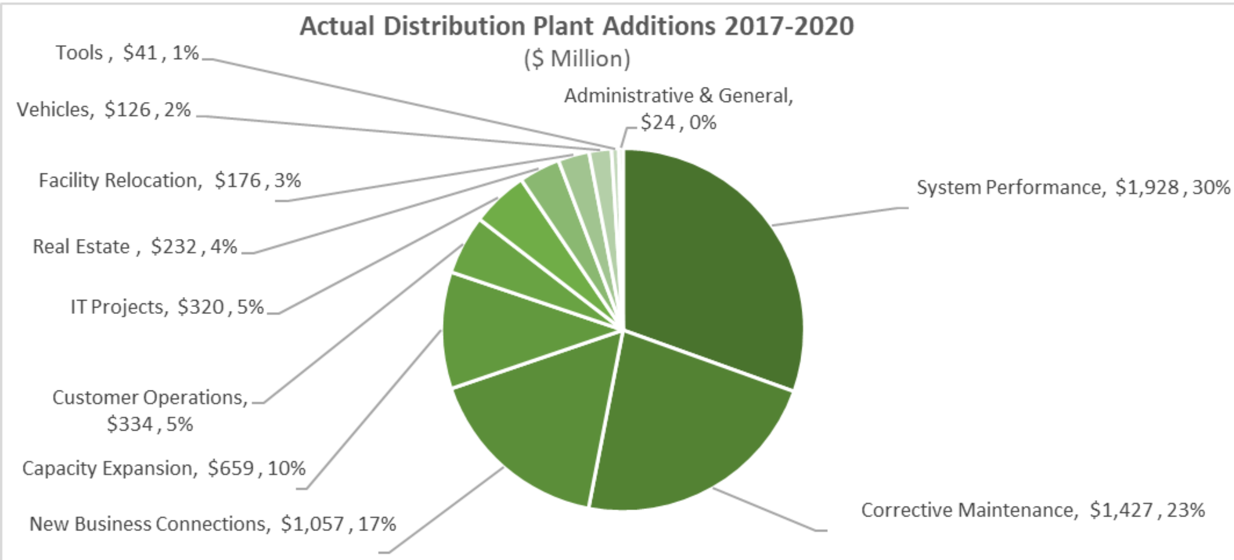


Figure 2-19. Actual Distribution Plant Additions by Investment Category

Table 2-3. Actual Distribution Plant Additions by Investment Category

Investment Category	2017 ($M)	2018 ($M)	2019 ($M)	2020 ($M)	2017-2020 Total ($M)
System Performance	549	471	380	529	1,928
Corrective Maintenance	331	331	357	408	1,427
New Business Connections	238	250	287	283	1,057
Capacity Expansion	98	175	204	181	659
Customer Operations	150	98	49	38	334
IT Projects	87	61	80	92	320
Real Estate	71	32	100	29	232
Facility Relocation	39	39	50	49	176
Vehicles	24	46	27	28	126
Tools	10	11	7	12	41
Administrative & General	10	5	4	4	24
Total	1,607	1,520	1,546	1,651	6,324

The chart and table above include plant additions related to distribution system assets and the allocated share of General & Intangible assets and exclude any coupled O&M investments such as Preventative Maintenance (including the vegetation management program) and the O&M component of Corrective Maintenance. The coupled O&M dollar amounts are excluded from the chart and table above as those spends do not include any distribution rate base plant additions.

In addition to the core distribution investments listed above, ComEd also has General & Intangible plant investments, which are essential to support critical delivery service functions and the core grid investments detailed in the table above.

ComEd uses General Plant assets to provide delivery services to its retail customers. There are several types of General Plant assets, and they do not necessarily physically deliver electricity. They include office buildings and the land on which such buildings are situated, office furniture and equipment, transportation equipment, and communications systems, including components of the SCADA system. In addition, General Plant includes the vehicles, tools, and equipment used by ComEd's employees in conducting ComEd's business.

Intangible Plant assets support ComEd's delivery services functions. For example, the largest category of Intangible Plant includes costs of capitalized software for computer systems that support delivery business functions, such as ComEd's retail billing systems and the assets related to its Call Center. In ComEd's case, virtually all of its Intangible Plant consists of major information systems used for electric system operation, restoration, work management, and retail customer service and billing.

The year-over-year plant investments are anticipated to evolve over time in response to stakeholder input, operational needs, regulatory mandates, and economic stimulus efforts. Each year, ComEd updates and reviews a 5-year forward-looking capital and O&M budget that is developed to meet ComEd's operational plans for providing safe and reliable service and achieving high levels of customer satisfaction in a most cost-effective manner.

3 Planned Investments

ComEd's planned investments allow ComEd to enable capabilities related to integrating additional and different forms of DER, beneficial electrification, and resiliency. ComEd identified the proposed investments based on expected grid and customer needs, new technology developments, and relevant power industry trends. In this regard, the Capital Investments Proposal is a solid foundation for meeting the objectives set by the Clean Energy Law as well as ComEd's basic utility service obligations, and it will evolve as part of the planning process. As noted in Section 1, the outcome from this process will inform ComEd's Grid Plan.

These investments are best estimates to address expected grid and customer needs and known policy requirements. Additional investments may be required to address other laws at the federal, State, and local levels. Given the uncertainty and unprecedented nature of the changes introduced by the transition to clean energy and climate change, adjustments to these investments will likely be needed in the future to ensure fitness to address actual needs, as well as full alignment with the State's policy objectives, including those described in the Clean Energy Law. Plans may also be affected by evolving technologies or other exogenous changes (e.g., macroeconomic changes, material shortages, etc.).

The next sections discuss changes to the energy delivery system and especially grid planning that are introduced by the adoption of renewable generation, DER, and beneficial electrification, the increasing impacts of climate change, the emergence of cyber and physical security threats, and the evolving needs of customers.

3.1 What Is Changing

The scale of transformation of the energy delivery system is unprecedented. The industry continues to work to identify suitable solutions to meet the associated challenges and realize the potential opportunities. Most importantly, the grid and the supporting utility systems are not fully prepared to address some of the evolving needs. Additional investments will therefore be required in monitoring, protection, automation, and control technologies, communication systems, and supporting analytics solutions.

Unless these changes are addressed through grid planning, system performance deterioration is a significant risk. As is the case with much of the North American electric grid overall, most of ComEd's grid infrastructure was designed and deployed before the recent wide-scale integration of DER or the recent rise in electrified transportation. As illustrated below, there has been a significant increase in the number of DER installations in recent years. Operational changes introduced by these new technologies require a new approach to engineering and design.

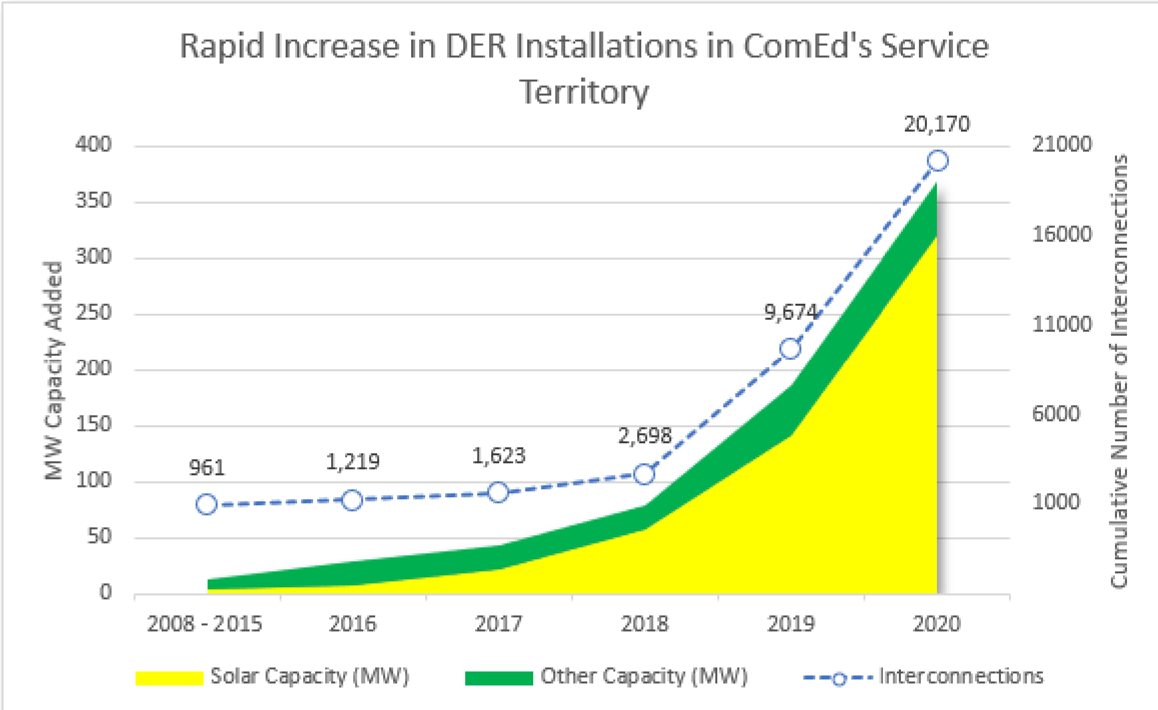
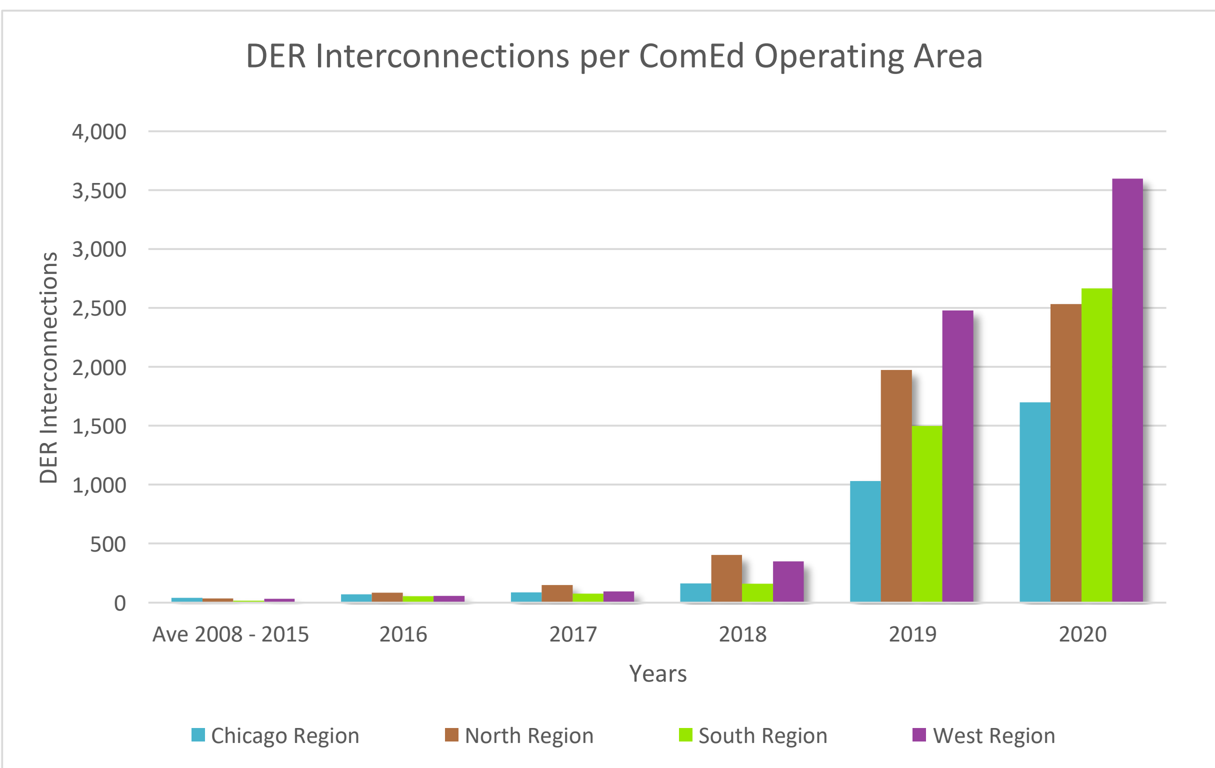


Figure 3-1. Rapid Increase in DER Interconnections

Figure 3-2. DER Interconnections by Operating Area



One set of challenges presented by certain renewable energy resources is the variability of their output. For instance, as illustrated below for the specific case of a PV plant, variability conditions can range from negligible on a clear sunny day to high in a day with scattered clouds. PV proliferation can cause two-way power flows, high voltage, voltage fluctuations, and power quality issues, among others. High variability of PV production can create variable power flows through distribution substations, feeders, and equipment, and cause voltage fluctuations that can impact the quality of electric service delivered to customers. An overcast PV profile means that the plant will deliver only a small percentage of the power it is intended to produce. This could represent a problem if, for example, the grid was planned assuming a reliable and predictable production from this facility, to be used to reduce the loading of a substation transformer or distribution feeder.

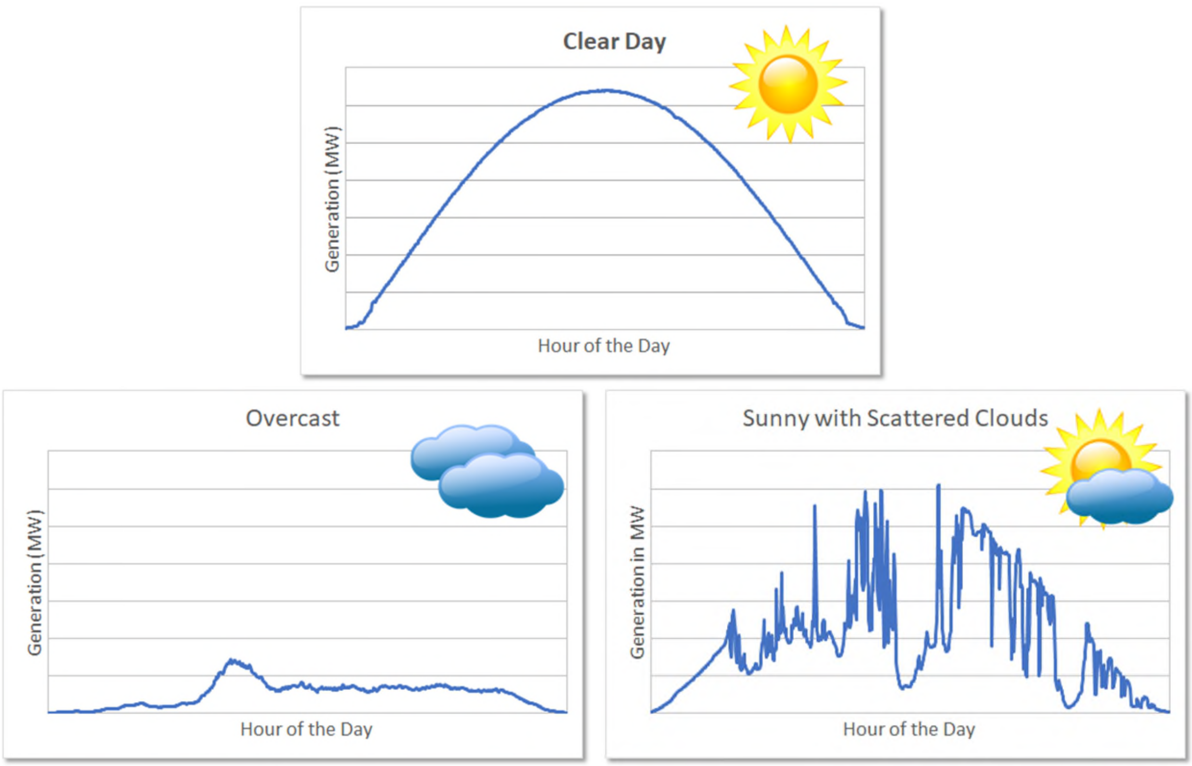


Figure 3-3. Variability of Solar PV Output[12]

If PV adoption is large enough, the amount of power produced by the PV plants can exceed the respective load of the equipment serving it. This would create reverse power flows (back feed) through the grid, i.e., the electric power will flow upstream, from customer premises to distribution service transformers and substations. Most distribution systems around the world were not designed for this type of operation, which can create additional challenges for existing voltage control and regulation equipment, protection systems, and overall utility practices, including safety.

[12] The three Solar PV production graphs are provided as illustrative data for typical days for the stated cloud cover. The data for the graphs are based on downloaded solar radiation data from the NREL Solar Radiation Research Laboratory, Baseline Measurement System; Golden, Colorado, using 1-minute measurements on select days in March and April of 2020. https://midcdmz.nrel.gov/apps/daily.pl?site=BMS&start=20200101&yr=2021&mo=12&dy=2

This type of situation is illustrated in the following figure, which shows electric power and voltages on a distribution service transformer that supplies a residential neighborhood with significant adoption of PV generation. When PV output is large enough (e.g., around noon), part of the production is consumed by homes, and the excess (the area shown in yellow) is exported to the grid. Since the grid was not designed for this type of operation, reverse power flow creates high-voltage conditions (the area shown in purple) that exceed allowable limits and can impact customer equipment. Additionally, given the variability of PV output, this type of operation can also create voltage fluctuations. Once PV production decreases and load increases (e.g., in the evenings or at night), power flow direction returns to normal operation (downstream), from the grid to homes, and voltage returns to acceptable limits.

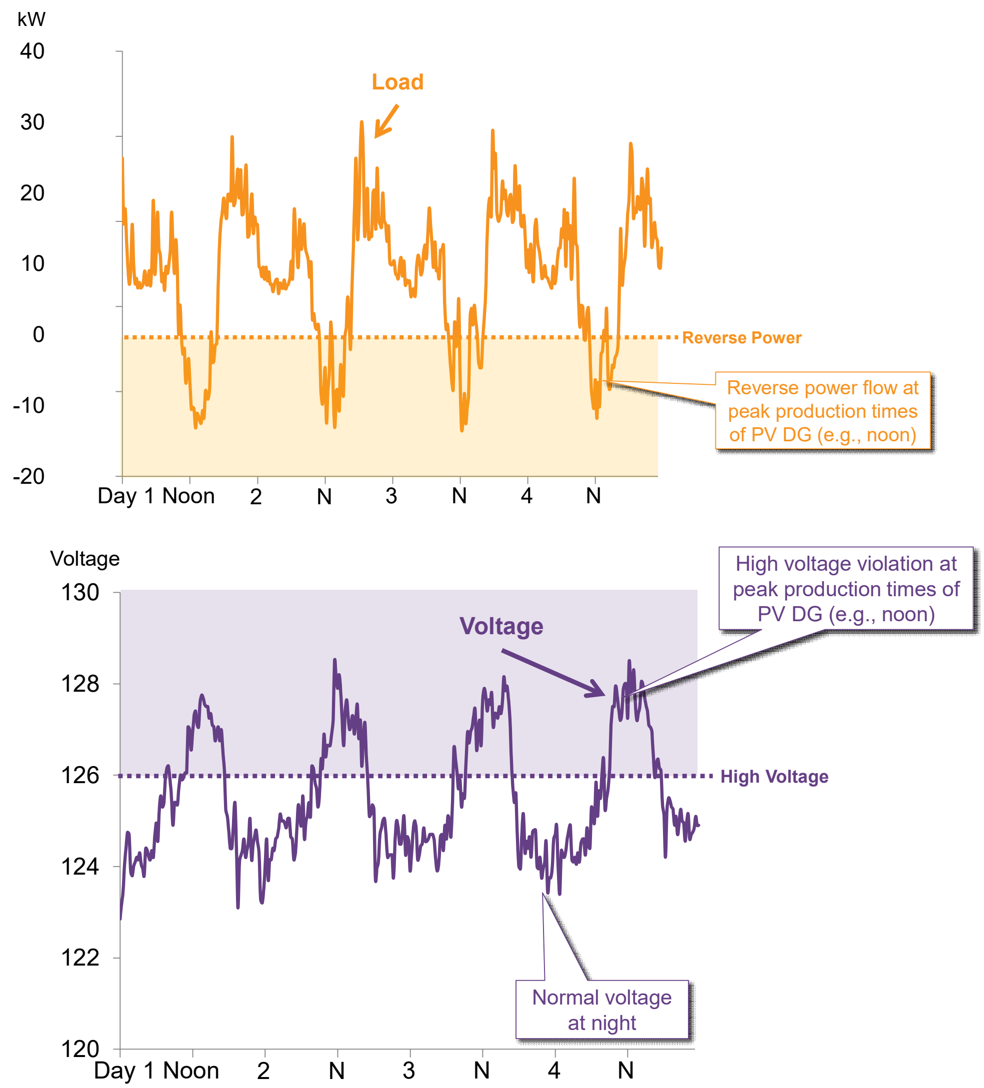


Figure 3-4. High DER Penetration Can Create Backflow and High Voltages[13]

[13] M. Asano, Grid Modernization Applications in a High DER Environment, 2018 IEEE PES T&D Conference and Expo, Denver CO.

This type of phenomenon is not exclusive to distribution service transformers and can also impact entire distribution feeders and substations. This is illustrated in the following figure, which shows how the average load of a substation transformer decreased over a period of three years due to the significant adoption of PV plants. Initially, PV production reduced the amount of load delivered by the transformer until it was large enough to offset the load and create reverse power flow conditions. Preparing the grid for this type of operation requires updating practices, standards, equipment specifications, planning methodologies, software solutions, and upgrading the infrastructure.

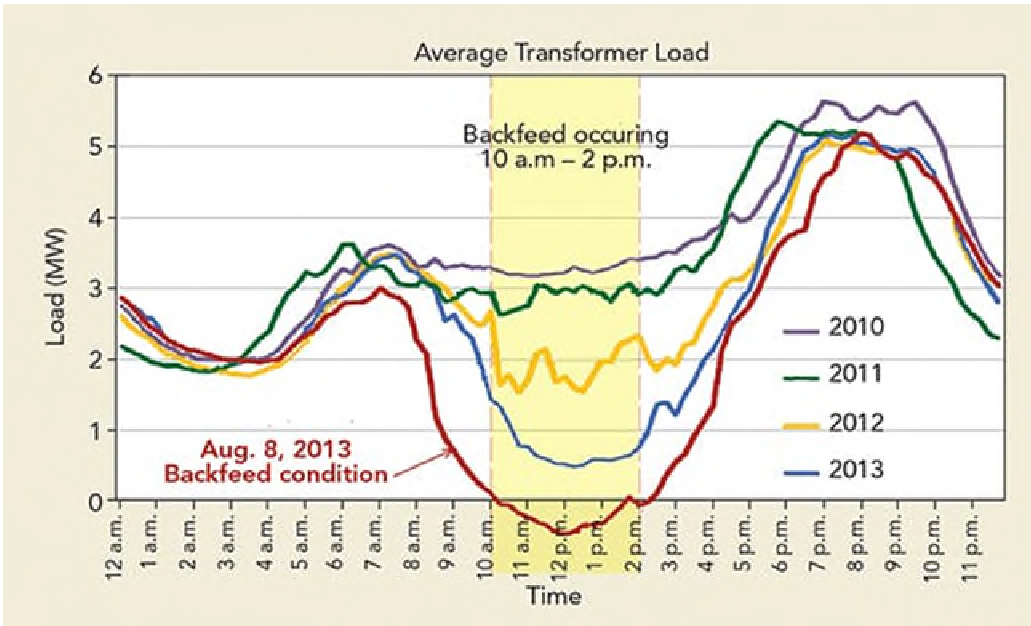


Figure 3-5. DER Induced Backflow Can Occur Even at the Substation Level[14]

DER integration also requires the utilization of more advanced and complex monitoring, protection, automation, and control systems, and high-speed communications infrastructure. For instance, when a fault occurs on a distribution system with high penetration of DER, grid protection systems locate and isolate the faulted area from the rest of the grid (creating an "island") to minimize the number of impacted customers and load. In some cases, DER unintentionally continues to energize the load in the island after disconnection from the grid and operates as a separate entity. Voltage in the island may initially increase significantly for a very short time, exceeding allowable limits, and then collapse once DER protection systems finally operate. This phenomenon, known as "unintentional islanding," is illustrated in Figure 3-6, below. The occurrence, magnitude, and duration of the high-voltage condition or temporary overvoltage are functions of specific grid design features and the amount of load and DER in the affected area. Preventing or mitigating this type of issue requires the utilization of advanced protection systems, such as Direct Transfer Trip, which rely on high-speed communications infrastructure (e.g., optical fiber technology) to ensure the simultaneous and coordinated operation of grid and DER protection systems to prevent temporary overvoltage.

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[14] D. Nakafuji, Visibility Enables PV Integration, T&D World, Aug. 2016. https://www.tdworld.com/grid-innovations/generation-and-renewables/article/20966763/visibility-enables-pv-integration

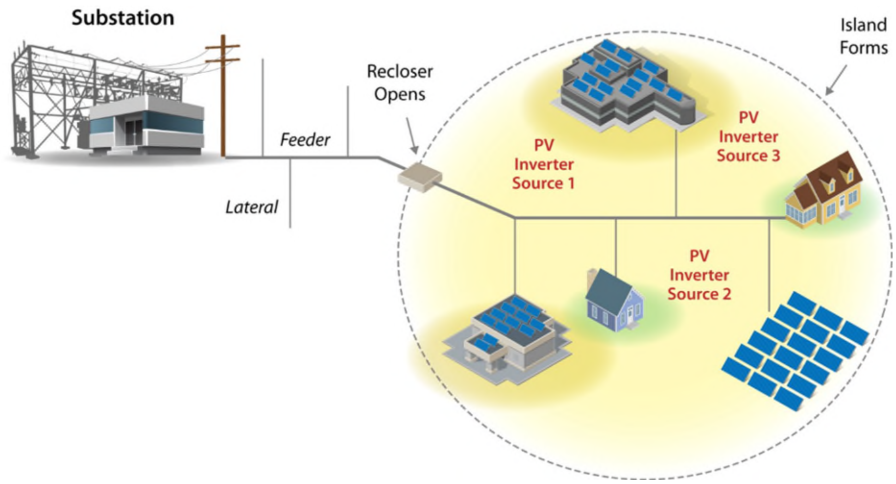

Figure 3-6. Unintentional Islanding[15]

These examples illustrate some of the complexities associated with designing, planning, and operating modern and future distribution grids. Therefore, the adoption of variable renewable generation requires careful evaluation of potential production scenarios and respective impacts to the grid and, if needed, the implementation of mitigation measures (e.g., investments in monitoring, protection, automation, and control technologies and communications systems) to ensure seamless integration. Energy storage solutions could provide an opportunity to address these and other challenges when operated in coordination with grid functions. NWAs like storage can be considered as an option when they provide the same level of benefits as traditional grid solutions in a cost-competitive manner.

DER integration challenges in utility distribution systems are well studied and documented topics of modern power systems engineering, additional information about DER impacts to various aspects of utility planning and operations can be found in numerous industry publications.

Additional Beneficial Electrification

The uncertainty on the generation interconnected to the distribution grid is exacerbated by increased uncertainty in electrical demand because of electric vehicles and other beneficial electrification end uses. These changes can lead to new peak loads, asset overload, and low voltage violations that ultimately impact the quality of service provided to customers. This is illustrated in the figure below, which shows how increasing adoption of electric vehicles (EV) can increase peak demands significantly. New peak demands could exceed allowable limits of substation transformers, which can trigger the need for new investments to upgrade infrastructure capacity (larger substation transformers and additional feeders).

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[15] Results from the DOE-CPUC High Penetration Solar Forum. https://www.energy.gov/eere/solar/downloads/results-doe-cpuc-high-penetration-solar-forum

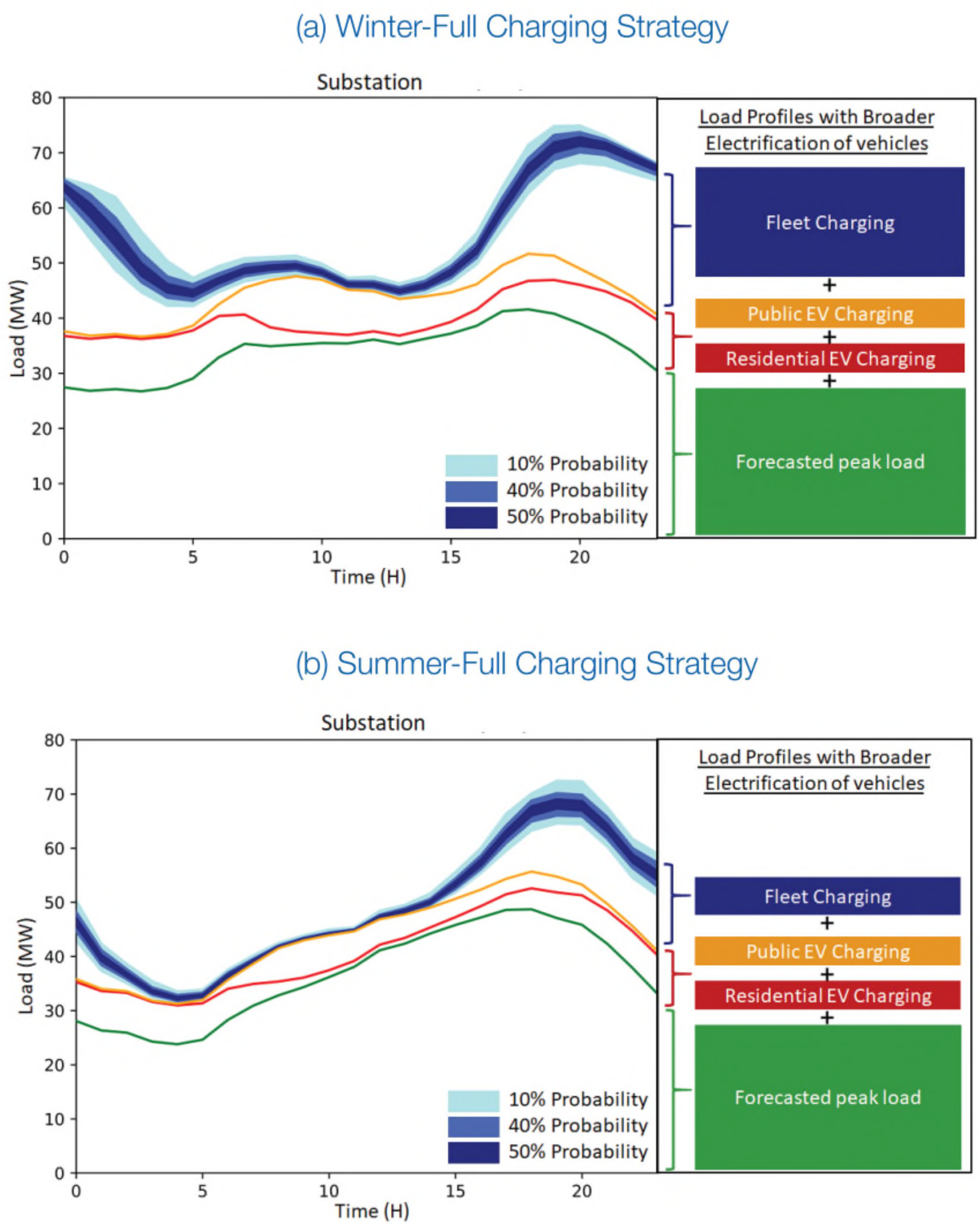

Figure 3-7. Impact of 100% Fleet, Residential and Public EV Charging at a Distribution Substation[16]

The magnitude and severity of these issues can grow significantly if, as expected, EV adoption happens across the service territory. This is illustrated in the figure below, which shows the projected weekday load increase due to EV charging in El Paso TX. The additional load that is

[16] National Grid & Hitachi ABB Power Grids, The Road to Transportation Decarbonization: Understanding Grid Impacts of Electric Fleets, Sep. 2021. https://www.nationalgridus.com/media/pdfs/microsites/ev-fleet-program/understandinggridimpactsofelectricfleets.pdf

projected to be integrated into the system is significant and will create the need for additional infrastructure investments.

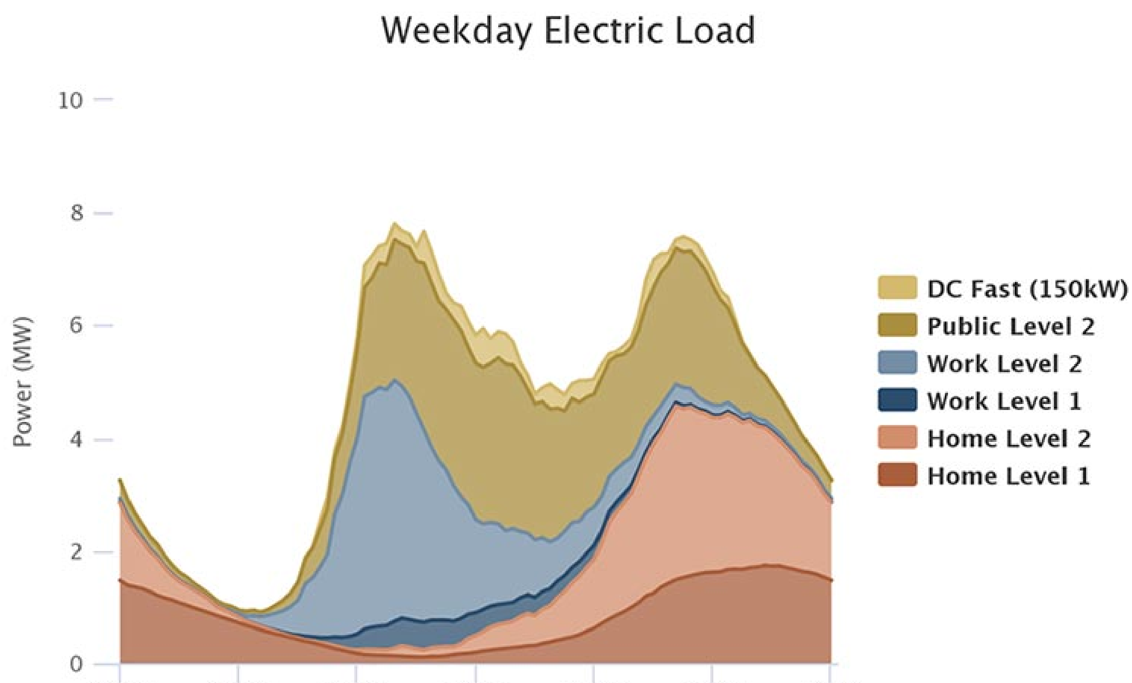

Figure 3-8. NREL EVI-Pro Forecast of EV Charging Load[17]

As shown in the figure below, the combined adoption of PV and EV technologies create additional challenges, which can significantly alter the traditional load profiles of distribution systems and create multiple issues for grid planning. For instance, these include: high voltage issues around noontime (during maximum PV production), and peak demand increase, overloaded assets, and low voltage conditions in the evenings (due to EV charging). Addressing these types of challenges requires investments in new technologies and infrastructure, as well as new planning and analysis methodologies and software solutions. Most suitable solutions often involve a combination of intelligent technology implementation and foundational infrastructure deployment.

Additionally, as more people increasingly rely on electric vehicles to meet transportation needs, the reliability and resiliency of the grid will become more important.

[17] National Renewable Energy Laboratory, "How Might Electric Vehicles Affect Electric Loads," Nov. 24, 2020. https://www.nrel.gov/news/program/2020/how-might-electric-vehicles-affect-electric-loads.html

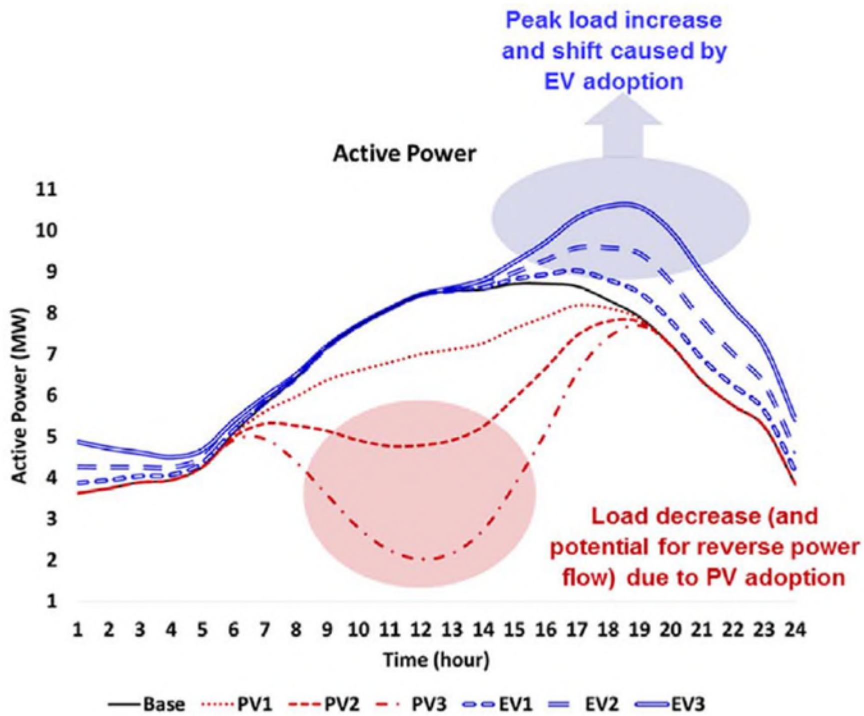

Figure 3-9. Combined High PV Penetration & High EV Adoption Will Completely Reshape Daily Loads[18]

ComEd has been monitoring these trends in order to be ready to transform the distribution grid and prepare it for this new reality, as discussed in the next section. On the timescales of grid planning, which looks years and even decades in advance, it is worth noting how rapidly these changes are occurring. DER and electric transportation adoption in ComEd's service territory in 2010 had been negligible, but a decade from now, they may contribute a sizeable percentage of total energy production and load, as envisioned by the Clean Energy Law, which has set the integration of one million electric vehicles by 2030 as one of its targets. Although the investments made by ComEd in the last 10 years have provided significant benefits, particularly in terms of reliability and resilience improvement, given the magnitude of ComEd's service territory, further investments are required to keep up with the changing landscape of energy.

Securing the Grid from Human-Made Threats

Intelligent electronic devices (e.g., smart meters, sensors) and communications systems are vital to enable the seamless integration of DER and beneficial electrification and to ensure the reliable, resilient, safe, and efficient operation of the grid. The deployment of these technologies should be accompanied by the implementation of cybersecurity measures to safeguard utility systems against potential human-made disruptions, including attacks from state actors. This is a rapidly growing area of attention given the increasing number of cyber events impacting the energy sector in the past several years. Examples of the most common attacks include distributed denial of

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[18] J. Romero Agüero, E. Takayesu, D. Novosel, R. Masiello, Grid Modernization: Challenges and Opportunities, The Electricity Journal, Volume 30, Issue 4, May 2017, Pages 1-6.
https://www.sciencedirect.com/science/article/abs/pii/S1040619017300660

service (DDoS), malware, ransomware, phishing, and data theft.[19,20] For instance, the following figure shows that DDoS attacks on utilities around the world in 2020, during the height of the COVID-19 pandemic, increased almost seven-fold compared with incidences of such attacks during the same period in 2019. Specific examples of cyber security events impacting the energy industry include: 1) a 2018 cyberattack that interrupted communications on the Midcontinent Independent System Operator (MISO); 2) the 2020 SolarWinds attack, which exposed a quarter of the electric utilities in the NERC footprint to a sophisticated malware inserted into the software supply chain; and 3) the Colonial Pipeline ransomware attack, which forced the company to shut down the pipeline defensively.[21] Other high-profile events (including the 2015 cyberattack on the Ukraine power grid, which caused an outage that affected almost a quarter-million people) have been reported around the world.[22]

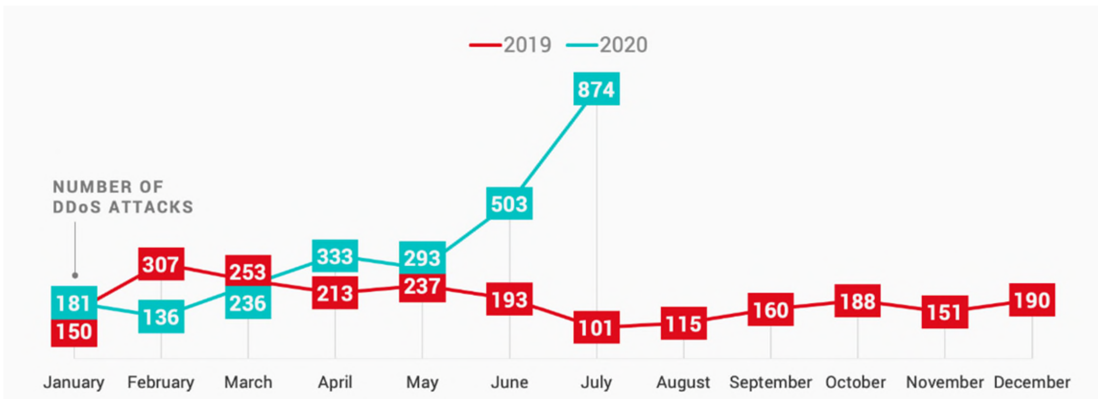

Figure 3-10. Cyber Attacks on Utility Systems are a Growing Threat[23]

Additional new threats to the grid involve physical attacks, such as sabotage of critical facilities like substations. From 2002-2012, approximately 2,500 physical attacks occurred against transmission lines and towers occurred worldwide and approximately 500 attacks against transformer substations occurred worldwide.[24] One of the most well-known physical attacks to the power grid of a U.S. electric utility happened on April 16, 2013, when a substation in Metcalf, CA, in the service territory of Pacific Gas and Electric (PG&E) was subject to a sniper attack. The

[19] NETSCOUT, which maintains a Cyber Threat Horizon tracker in real time https://horizon.netscout.com/, recorded 1,780 DDoS attacks against utilities worldwide from June 15 to Aug. 21, 2020 representing a 595% year-over-year increase. This type of attack uses multiple platforms to try to flood, overwhelm and render a target's information system unavailable. While the attack is in progress, companies are unable to access and use the affected information systems, which may impact vital services.

[20] J. Miller, Cybersecurity for Utilities: Municipal Utilities Have Become a Major Target. https://www.bitlyft.com/resources/cybersecurity-for-utilities

[21] Sophisticated hackers could crash the US power grid, but money, not sabotage, is their focus. https://www.utilitydive.com/news/sophisticated-hackers-could-crash-the-us-power-grid-but-money-not-sabotag/603764/

[22] L. Doan, Colonial Is Just the Latest Energy Asset Hit by Cyber-Attack. https://www.bloomberg.com/news/articles/2021-05-08/colonial-is-just-the-latest-energy-asset-hit-by-cyberattacks

[23] Worldwide Denial-of-Service Cyberattacks on Utilities Up Seven-Fold This Summer, Data Shows. https://morningconsult.com/2020/08/27/cyber-attacks-gas-electric-utilities-data/

[24] T.M. Wintch, PERSPECTIVE: Cyber and Physical Threats to the U.S. Power Grid and Keeping the Lights on. https://www.hstoday.us/subject-matter-areas/infrastructure-security/perspective-cyber-and-physical-threats-to-the-u-s-power-grid-and-keeping-the-lights-on/

attackers fired more than 100 rounds of .30-caliber rifle ammunition into the radiators of transformers, causing oil leaks, equipment overheating, and shutting down. The assault lasted 19 minutes and caused $15 million in damage.[25] Future investment plans must continue preparing the grid for these types of growing threats.

Impact of Climate Change

There are also benefits to the distribution grid from the integration of technologies and other investments being planned and made to mitigate climate change. More broadly, the deployment of infrastructure to support the integration of DER can provide additional opportunities to address grid needs in a cost-effective way. Given customers' evolving expectations and needs regarding reliability, resilience, and power quality, and the increasing frequency of major weather events, these opportunities are increasingly important.

Climate change impacts are expected to continue increasing in the ComEd service territory. For instance, as illustrated below, the number of annual days with a maximum temperature greater than 95°F is expected to steadily increase over the next decades in Northern Illinois. Currently, Illinois averages 5 days a year classified as dangerous or extremely dangerous according to the National Weather Service (NWS) Heat Index. By 2050, the State is projected to see a 10-fold increase to nearly 50 days a year. By 2050, the typical number of heatwave days in Illinois is projected to increase to more than 60 days a year from the present typical total of 10 days a year. This will cause significant stress (e.g., increase in operating temperature) on critical distribution system assets, such as substation and service transformers and underground cables. These can lead to failures and service interruptions.

The impact of temperature rise on loads and equipment is a critical challenge for distribution grid infrastructure and addressing this increasing problem will require additional studies and investments. Long-range climate forecasts predict not only rising daytime peak temperatures but also that nighttime temperatures will be higher with less overnight cooling – temperatures will be elevated throughout the day and night. This not only increases the peak energy demand using today's temperature sensitivity calculations, but will affect thermal storage behavior in buildings and likely further increase off peak loads. All this means that T&D apparatus that literally heats up with resistive heating at peak loading will not cool down as much off peak. This places additional stress on apparatus, decreasing lifetime and increasing failure rates. Worse, during routine "N-1 outage" conditions when there is a failure of one piece of apparatus such as a power transformer in a substation, the "emergency loading" on remaining apparatus is far greater and has a more severe effect on the condition of the surviving transformer. ComEd will need to review and update equipment standards, specifications, and planning practices, as well as upgrade and replace assets and overall infrastructure to prepare it to operate in this new reality.

[25] J. Paglieri, Sniper attack on California power grid may have been 'an insider,' DHS says. https://money.cnn.com/2015/10/16/technology/sniper-power-grid/index.html

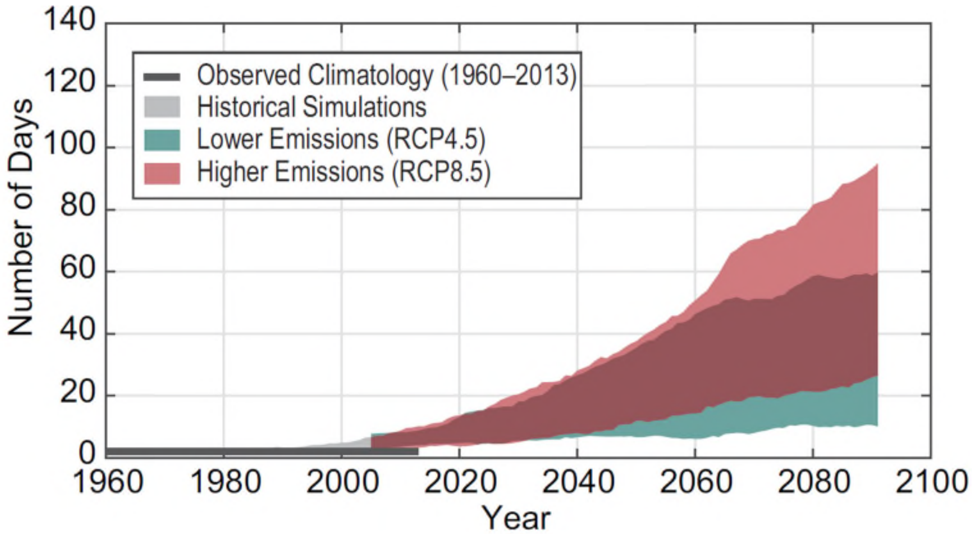

Figure 3-11. Annual Days with Maximum Temperature ≥ to 95°: Northern Illinois[26]

Climate change is expected to create other challenges as well. For instance, as shown in the figure below, it is expected that winter precipitation in Illinois will grow through this century, and due to rising temperatures, there will be more rain than snow, which is likely to increase the risk of flooding affecting electric infrastructure. This figure shows projected total precipitation for winter (December, January, and February) for higher (red) and lower (blue) emissions scenarios, historical values are shown in black. Preparing the grid to withstand these types of impacts prompted by climate change will require additional investments in weather hardening infrastructure and technologies.

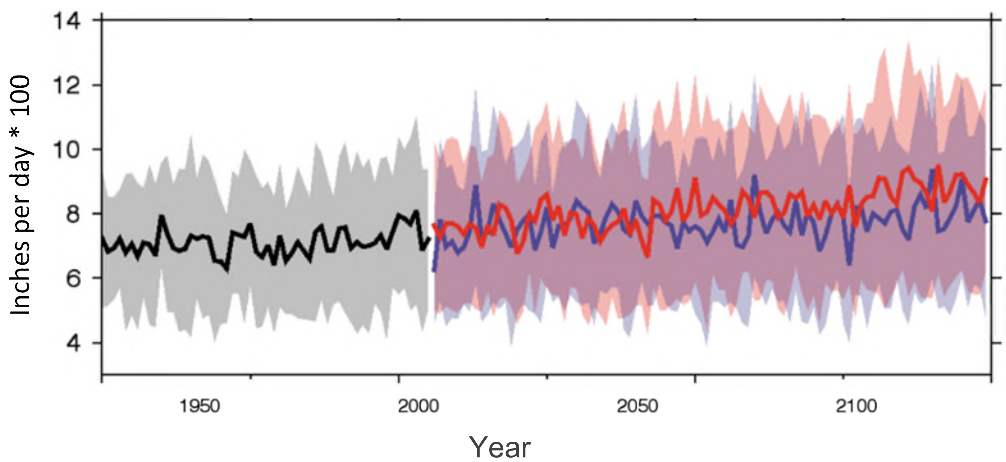

Figure 3-12. Forecasts Show Continuing Increase to Precipitation Levels[27]

[26] An Assessment of the Impacts of Climate Change in Illinois. https://www.nature.org/content/dam/tnc/nature/en/documents/IL_Climate_Assessment_2021.pdf

[27] Climate Change State Profiles: Illinois. https://www.geo.umass.edu/climate/stateClimateReports/IL_ClimateReport_CSRC.pdf

While these opportunities for grid improvement will seek to address the changing climate and energy system, grid upgrades also serve traditional grid needs in new ways. The adoption of new technologies and interoperable devices that automatically address real-time system needs will enable new capabilities and allow further improvement of overall operational efficiency, including the availability of abundant, up-to-date and accurate asset and grid performance data, enhanced situational awareness, more efficient outage management and restoration, and overall energy efficiency. ComEd uses its distribution planning process to identify solutions that prepare for a changing grid while stewarding the existing grid to improve its performance.

Like other parts of the North American grid, ComEd's system is aging. As overhead and underground lines and equipment are exposed to weather and the stresses of use, reliability and resilience issues can increase. It is sometimes better to replace obsolete or aging equipment than to adhere to the constraints of legacy designs. To weather the storms of climate change and to extend the capabilities of the distribution system, the foundational electrical and supporting communications infrastructure must be in good condition. Although improvements have been made in the past decade, significant portions of the grid still require investment to address some of these needs (e.g., replacing deteriorated or obsolete assets) and to prepare it for the future. Without careful ongoing plant maintenance and updating, the stresses of beneficial electrification, increasingly severe weather, and intermittent distributed generation can result in unacceptable system performance.

These multiple changes and challenges emphasize the fact that distribution planning is a complex endeavor involving multiple objectives that pertain to the different features of modern grids. This includes consideration of traditional targets, such as affordability, accessibility, safety, and reliability, along with evolving goals, such as clean energy adoption, security (cyber and physical), resiliency and adaptability, and flexibility. Additionally, there is an increasing convergence between 1) distribution engineering and planning analyses, 2) transmission and distribution planning, and 3) overall planning and operations activities. In summary, the power delivery grid is rapidly transitioning to a complex and dynamic cyber-physical system. Planning this modern grid requires accurate and up-to-date data, advanced modeling and analytics capabilities, and integrated software solutions. IT infrastructure and systems will play an increasingly critical role in this evolution.

3.2 How ComEd is Preparing

In conjunction with this Capital Investments Proposal, ComEd continues to assess the expected impact of new technology adoption and identify investments to prepare the grid accordingly, including improved real-time monitoring, protection, automation, and control. ComEd also identified investments to address needs driven by climate change, system growth, asset condition, obsolescence, reliability, resilience, power quality, safety, and security.

ComEd identifies proposed investments through industry-accepted distribution planning practices, including load forecasting, grid modeling and simulation, risk analysis, and prioritization. Plans are reviewed and approved by ComEd's distribution planners, subject matter experts, and executives. The proposed investments target high-priority areas and needs for the next 5 years. ComEd's studies rely on granular modeling of the grid to identify poor-performing system components within ComEd's service territory and target investments to address those specific components in a cost-effective way.

Developing future Grid Plans to address imminent grid and customer needs will require enabling additional capabilities and making further investments. Identifying cost-effective opportunities for NWA and conducting the detailed locational and temporal analyses of distribution grid performance described by the Clean Energy Law will require enabling advanced analytics capabilities and deploying additional infrastructure (e.g., sensors, communications, and enterprise systems) to collect and process granular geospatial and high-resolution data, including at service transformer and DER level. Additionally, monitoring and managing in real-time thousands of DERs, electric vehicle charging stations, and other intelligent devices to operate the grid in an efficient, automated, secure, safe, reliable, and resilient way will require sophisticated information systems, such as Advanced Distribution Management System (ADMS) and Distributed Energy Resource Management System (DERMS) to oversee the entire service territory.

ADMS brings SCADA to the distribution circuit – the ability to monitor field apparatus, loadings, and voltage levels in real time and to operate switches and other controllable devices. It also brings advanced analytics such as network analysis and optimization to the table (thus "Advanced" in ADMS), just as advanced analytics have become commonplace in transmission operations. These analytics will allow grid operators to keep grid conditions within safe parameters and react to changing conditions.

DERMS provides communications, monitoring, and control of DER such as behind the meter battery energy storage or smart EV charging. DERMS is the distribution equivalent of generation control systems long in use in the bulk power world. DERMS will allow the grid operator to manage the energy production and usage of participating DER, with their owner's consent to participate, to enhance reliability, improve economics, and enable higher DER penetration.

The purpose of these technologies and their use is indicative of a paradigm shift in distribution utility operations. In the "old world," the distribution system was largely operated in a "passive" fashion – it was designed and constructed to deliver power without any operational oversight beyond the substation. Distribution operations largely consisted of managing and overseeing field work, especially for public and crew safety, and for coordinating major field system restoration activities after an outage. That is no longer the case.

As the planning and operation of the grid becomes more complex, the skillsets of the grid planners and system operators also need to evolve. In the "new world," distribution operations will become "active" and "dynamic" as has been the case in the bulk power world for decades. Operators will make use of advanced analytics to plan grid and DER operations in the short and medium term, and to react in real time to grid conditions and DER production. This means that new distribution operations procedures and practices will have to be developed and validated, and that operators will have to be trained in their use. The training will have to include not only the procedures but the engineering basis behind them and will inevitably include simulator training for individual operators and for the operations team.

Operators and planners need to be more aware and fluent in rapidly changing technologies along with their impacts on the grid such as those described in the previous section. Increased analytical skills will become foundational to understand the impacts of new technologies on the grid and to understand how it will respond, in order to maintain a safe and reliable service to customers.

All this evolution is going to have to take place at a much more rapid pace than it took in the transmission / bulk power space, driven by the urgent imperative to de-carbonize electricity production and electrify energy usage. Significant work is ahead, and major investments will be required.

Emerging grid challenges require development and demonstration of new technologies and capabilities that will point the way to providing a higher level of service across the region. In order to prepare for the changes introduced by climate change and proliferation of customer side technologies, demonstration projects are of critical importance to adapt the grid for these challenges. ComEd has initiated several demonstrations of smart grid key technologies, such as microgrid, battery energy storage, extra fast charging technologies for EVs, machine vision for detecting ice loading on distribution lines, etc. ComEd is currently investigating and testing these technologies and their technical feasibility for broader future grid solutions to evaluate how they can transform the function and operation of the grid to meet challenges.

In addition, ComEd is working closely together with leading technical universities, national laboratories, vendors, and international industry groups to develop and demonstrate a portfolio of technologies that have the cumulative capabilities necessary for observability and controllability to achieve performance needs of the future grid. ComEd currently has a portfolio of 18 active federally funded projects allowing us to leverage resources from the Department of Homeland Security (DHS), the Department of Energy (DOE), and the National Science Foundation (NSF) to develop and demonstrate new grid capabilities. Beyond the projects alone, these partnerships produce emerging best practices that inform the work that we do across our service territory and drive the industry as a whole to produce additional capabilities and insights that help ComEd meet its responsibilities in Illinois. All these efforts inform ComEd's planning for a grid that achieves the State's policy goals and meets the evolving resilience needs of society.

The next section discusses the components of ComEd's proposed capital investments, which represent the starting point for the development of the broader Grid Plan outlined by the Clean Energy Law.

3.3 What Is Planned

ComEd's proposed capital investments are intended to address multiple objectives and grid needs comprehensively via a diverse portfolio of projects. The objectives of the proposed investments comprise traditional power delivery goals, including safety, affordability, reliability, and accessibility, along with new and evolving targets, such as integration of clean energy and beneficial electrification, resilience, security (physical and cyber), flexibility, and adaptability.

The proposed investment portfolio consists of the deployment of foundational assets, such as distribution lines, underground cables, transformers, and substations, along with the implementation of intelligent devices, technologies, and information systems. These investments will leverage modern protection devices (e.g., digital relays), DA solutions, sensors, communications systems, and utility management systems (e.g., ADMS and DERMS) to continue providing high levels of service and system performance.

The proposed investments include those needed for system performance, corrective maintenance, new business connections, capacity expansion, customer operations, and facility relocation.

3.3.1 System Performance

The proposed investments are intended to maintain and improve safety and grid performance (e.g., reliability, resilience, etc.). Details of several of the core investments are included below. Other investments included in this category are intended to demonstrate technology solutions, concepts, and methodologies to mitigate the impacts of climate change and integrate high levels of DER. The learnings and insights from these projects will be used to validate expected benefits and costs to inform whether they should be implemented in larger-scale deployments. Ongoing investments in sensors, managed charging, and DERMS are examples of some of these programs.

- The **Substation** investment plan addresses the safe, reliable, secure, and resilient operation of the grid through substation hardening, programmatic replacements of transformers, distribution circuit breakers, obsolete circuit breakers, substation batteries and other major equipment, ground grid and lightening mitigation, flood protection, substation security, wildlife protection and substation fire protection.

    - The **Substation Hardening** program aims to maintain or improve system reliability by replacing aging or poor performing assets such as transformers, switchgear, breakers, circuit switches, capacitor banks, batteries, switches, electro-mechanical relays, and other pertinent equipment needed for the reliable and resilient operation of both transmission and distribution substations. This equipment is risk scored based on a historical review of field failures and findings from preventative and corrective maintenance activities. The planned replacement of the highest risk scored equipment avoids impending emergent failure and large-scale customer interruptions or significant events.

      Hardening also encompasses substation resiliency, including sump pump replacement, roof/building repairs/replacements, grounding grid, drainage, and flood mitigation. Building a flood-resilient facility is critical in preventing damage to electric equipment and avoiding costly repair/replacement costs caused by a severe flood event. Installation of flood forecasting & detection system, floodwalls, water pumping systems, and monitoring at high-risk substations help provide advance warning alarms and improve flood response protocols. Substation grounding grid hardening programs address ground grid degradations that have been identified through ground grid testing. Proper ground grid connections are critical for reliable operation of relaying, communication, and SCADA equipment within the substation. A safe ground pathway ensures the safety of the employees operating this equipment.

    - The **Transformer Replacement** program replaces old or poor performing transformers, reducing the risk of an emergent failure and a large outage or significant event. Replacements are prioritized based on each transformer's material health condition. The material health condition is comprised of both qualitative and quantitative data including dissolved gas analysis (DGA) or oil quality, EPRI's Normal Degradation Index, electrical and acoustic testing and industry known design and failure issues that may affect their continued operation. This program also ensures that a sufficient stock of spare transformers is available for emergent replacements.

    - Other **Programmatic Replacements** aim to maintain or improve system reliability by replacing aging or poor performing assets such as circuit breakers, obsolete disconnects and reclosers, and batteries. They are based on age, material condition, obsolescence, and historical reliability. Replacement of poor performing circuit breakers and other major assets reduces the probability of large-scale customer interruptions. Ground grid and lightening mitigation are based on programmatic testing and engineering studies of the stations' grounding to ensure personnel safety and reliable operation of equipment.

- The **Flood Mitigation** program investments are made based on an assessment of more than 800 substations. The assessment classified each of the ComEd properties into flood risk levels from low to severe based on total population served and critical infrastructure supported. Flood mitigation efforts, including flood walls, water lift stations, and river level monitors, were designed and are being constructed at 30 high risk substations starting with the highest potential impact substations.

- The **Substation Security Program** is a NERC CIP-014 compliance initiative, and proactively seeks to improve substation security across the ComEd service territory by physically securing critical infrastructure assets. The stations, categorized into three tiers, include various levels of security requirements. This program also encompasses smart lighting upgrades to help ensure safer and more secure substations for personnel and enhances the way security can monitor the substations.

- Other programs such as **Fire Protection Improvements** ensure compliance with local fire codes and training of local fire departments to aid in safe fire response.

- The **Wildlife Mitigation** program proactively seeks opportunities to install wildlife protection throughout the substations to prevent wildlife deaths and outages from wildlife grid contact.

- **Protection and Control** invests in modernization of ComEd protection and the SCADA system by eliminating legacy relay and SCADA equipment and replacing them with microprocessors and modern SCADA equipment. Modern relays and SCADA allow for faster tripping schemes, remote monitoring, advanced data analytics, automatic fault record retrieval, and fault locate capabilities to streamline restoration efforts. Modern equipment also helps mitigate impact to customers by preventing mis-operations, minimizing momentary outages, shortening outage duration, and minimizing equipment fault damage.

  - The **Distribution Relay Upgrade** program: The objective of protective relays is to isolate faults as quickly as possible while isolating only the faulted circuit or circuit section to minimize system and customer impact. ComEd maintains a large fleet of electromechanical relays (in the tens of thousands) on the system and has active programs to upgrade and replace units with the new and more intelligent microprocessor-based versions which enhance communication-based protective schemes that allow faster protection to mitigate momentary outages.

    Approximately 2,100 ComEd distribution circuits use electromechanical relays that are unable to support the bi-directional power flow operation that is expected as DER penetration levels increase. The new microprocessor-based protective relays can recognize the bi-directional current flow condition required for protection in the case of high DER penetration.

  - The **Bus Protection Upgrade** program: A large portion of ComEd distribution buses do not have high-speed bus protection schemes. Legacy scheme fault clearing times are in the seconds range while high-speed schemes clear faults in 0.1-0.3 seconds. Faster bus protection schemes limit fault damage and minimize or practically eliminate the likelihood of fault migration and associated higher customer impacts.

- The **Transformer Protection Upgrade** program: ComEd has hundreds of distribution transformers (138/12kV and 138/34kV) with electromechanical relays. Transformer protection upgrades to microprocessor relays provide increased reliability by minimizing false trips, providing additional data analytics, and allowing improved coordination with other schemes to ensure transformer availability.

- The **Substation SCADA & Associated Communication Upgrade** program: The installation of advanced SCADA RTUs, communication equipment, equipment monitoring systems, and implementing modern communication standard (IEC 61850) at these stations will enable event reporting for data analytics, automated fault locating, FLISR (Fault Location, Isolation, and Service Restoration), and self-monitoring. ComEd is targeting these installations for locations with high penetration levels of DER. The remote monitoring and advanced analytics enable automatic fault record retrieval and fault locate capabilities to streamline the restoration efforts, prevent mis-operations, shorten outage duration, and minimize equipment fault damage.

- The **Intelligent Substation** program: This program consists of upgrading electro-mechanical relays to modern microprocessor-based devices providing thorough information including automated 12kV feeder fault analysis, and replacing outdoor legacy busses and aging circuit breakers to eliminate reliability concerns. Upgraded SCADA equipment combined with modern relays provides two-way communication between the ComEd control center and each substation. The intelligent substation program enables advanced pre-failure detection (advanced transformer monitoring, slow breaker clearing times) and analysis, which helps predict a variety of failure modes (transformer degradation, pending breaker failure, etc.).

  Annual maintenance activities (Corrective Maintenance-CM & Preventive Maintenance-PM) are also optimized at these stations by the utilization of modern technology that automatically monitors the health of significant substation assets. The intelligent substation also provides all the advantages of modern relay schemes noted above.

- The **Transmission – High Voltage Distribution (HVD)** investment plan is currently comprised of 69 kV and 138 kV HVD programs from the following investment types, which are balanced to address safety, environmental, reliability, and resiliency performance at systemwide levels:

  - The **Wood Pole Replacement** program replaces existing HVD wood structures with steel structures based on age, health index, and customer count. This program increases customer reliability and adds resiliency to the HVD system, especially during extreme weather events. Steel structures are more resilient, reducing outage duration and emergent costs due to wood pole or component failures.

  - The **Wood Structure Cascading Mitigation** program replaces wood structures with steel to eliminate cascading failures of multiple structures during weather events. ComEd chooses the structures based on health index, age, line operation, and customer impact. The steel structures are strategically placed to mitigate/reduce wood pole failures on a line, reducing restoration time and increasing system resiliency.

- The **Wood Crossarms and Tension Brace** program addresses end of life crossarms and tension braces based on health index, age, system operation, and customer impact. This reduces emergent repairs, minimizes line operations, and increases system resiliency.

- The **Cable, Joint, and Termination** replacement program is a multi-year program consisting of replacing existing High-Pressure Fluid Filled (HPFF) cable, also referred to as pipe-type cable. The HPFF lines in the program are the first HPFF pipe-type systems installed in the early 1950s. The replacement will include new cable, joints, and terminations. The new equipment will increase reliability, reduce maintenance costs, and enable future upgrade capabilities.

- The **Pumping Plant** replacement program is a multi-year program that replaces obsolete pumping plant equipment that has reached end of life or requires extensive maintenance. The pumping plants are critical to the operation and reliability of the HPFF systems. This program increases reliability and reduces potential environmental impacts.

- The **Cable Removal** program is a multi-year program to remove retired Low-Pressure Fluid Filled (LPFF) Cable Systems and Paper Insulated Lead Cable System (PILC). These circuits have been retired in place and replaced with fluidless XLPE cables. The removal includes LPFF/PILC cable, joints, terminations, fluid reservoirs, and all accessories associated with the cable system, which removes asbestos-containing material, lead, and dielectric fluid used in traditional cable systems. The removal of the retired LPFF/PILC cable and accessories removes the environmental hazards associated with fluid-filled cable systems reducing maintenance expenditures.

- The **Back-up Generator (HVD) Replacement** program is a multi-year program to replace obsolete auxiliary backup generators for pumping plants. This program reduces maintenance costs and mitigates customer outages by sustaining the pumping plant during an outage, increasing the overall reliability of the HVD System.

- The **Distribution** plan is currently comprised largely of the following program investments, which are balanced to address safety, reliability, and resiliency performance by cause at both systemwide levels and in "pocket areas" as outlined in the Distribution Reliability Improvement Programs procedures. The programs are designed to first address the critical needs identified in the distribution asset health assessment for the respective assets, maintain system reliability, address worst performing circuits and customer service needs, and then continue to build the critical capabilities to maintain the safety and reliability of the system while simultaneously integrating increasing quantities of DER, amidst a changing climate.

  - The **DA** programs include the 4/12 kV circuit recloser program, DA Lateral program, 34 kV Circuit program, and line sensors.

    - The **4/12 kV circuit recloser program** consists of installing intelligent reclosers and switches strategically across the distribution system to enable automatic isolation, reclosing, and reconfiguration in response to grid changes and disturbances. This program will foster greater automated and remote control of system load and balance through real-time efficient operational flexibility. A key program objective is installing these devices to divide distribution feeders into smaller "segments" (with 400 to 750 customers), which will effectively minimize the number of customers impacted by any single event on the distribution system. These intelligent devices can: 1) be controlled remotely via SCADA, which provides operators with remote control capabilities of grid configuration and operation; and 2) collect electric variable data in real-time, which helps improve system awareness and visibility and enables predictive analytics capabilities. The real-time system measurement capability and base analytics help offset or reduce preventative and corrective maintenance costs by offering insights into equipment and circuit health that allow for less frequent and more targeted truck rolls. When combined with higher communication speeds and bandwidth facilitated by optical fiber or high-speed wireless, the sensing data allows for increased detail in power quality measurement, and at low enough latencies, the capability to improve power quality through reduced momentary events and shorter ride through time requirements for sensitive loads. The DA devices in combination with necessary communications are fundamental to the safety and resiliency needs required to protect distribution circuits with bidirectional power flow and maintain power quality for customers. The current investment planning for this program prioritizes dividing up the largest customer segments on the system, such as those that contain up to 1,500 customers who might be interrupted by a single event on the system (for example, a dig-in or car striking a pole) and dividing them up into smaller segments with alternate sources that can automatically restore the respective groups of customers. In addition to segments with the largest numbers of customers, the program targets those with the highest level of overhead and underground circuit mileage or "exposure" to failure and those with the worst performance history first. Another important objective that ComEd will continually refine in the circuit recloser program planning is providing the necessary reliability on those line segments where clean energy sources will be integrated to protect sensitive customer loads.

- The **34 kV DA program** consists of installing telemetered sectionalizing switches and reclosers on 34 kV circuits to provide additional segmentation of the sub-transmission system and operational flexibility. ComEd has evolved the program throughout its inception in the early 1990s from focusing solely on the protection of distribution centers (DC) to further segmenting the DC's transformers for additional reliability benefits. ComEd has also evolved the program to include the installation of more fault interrupting devices to provide improved resiliency and power quality and mitigate some momentary system events. The current investment planning for this program prioritizes the installation of fault interrupting devices on 34 kV lines which serve the greatest number of customers, have the greatest overhead exposure, and have experienced the poorest historical performance. Another important objective that this program will continue to support is power quality improvement to support improved integration of clean energy sources and protect sensitive efficient customer loads.

- The **DA Lateral program** is intended to improve reliability on the worst-performing taps and prevent outages from temporary faults. The program prevents temporary overhead faults from resulting in sustained outages for customers and thereby reduces the number of truck rolls and consumption of operational resources. It also provides necessary improved visibility and control with solid-state relaying. The program transitioned to using telemetered vacuum reclosers in 2021 to provide protection as well as data logging and communications capabilities. These are an upgrade from legacy reclosing technologies to lateral programs deployed previously as they had limitations with coordination and visibility. The current program reclosers employ a fully programable relay to allow for coordination in all applications and enable current monitoring and advanced protection techniques. The program prioritizes fuse tap locations with the greatest customer impacts, largest overhead exposure, and poorest reliability performance, or is utilized in targeted designs for customers whose service reliability is below target.

  - The **DA Line Sensor program** targets the installation of intelligent communicating distribution line sensing devices. These devices measure electrical parameters and provide real-time monitoring of circuit conditions. Line sensors with remote communications help to identify the source of system faults and disturbances faster and enable more efficient operational response and restoration for customers targeting improvements in CAIDI. These sensors also employ high sampling rates to enable disturbance monitoring of those events that do not result in system protection devices operating, better monitor power quality, and build preventative and predictive analytics that allow identification of conditions before they result in outages to customers on the system. Current investment planning targets the eventual installation of approximately 33,000 sensors across all the 4/12 kV feeders at an initial density of 6 sensors per distribution circuit.

- The **Renewable Energy, Advanced Control, and Telemetry Systems (REACTS)** program designs and constructs the communication and telemetry network required to maintain a safe, secure, flexible, resilient, and integrated electric distribution grid. It includes upgrading existing communication systems that do not support current equipment interoperability, remote telemetry, and distribution system protection standards. The program includes distribution system upgrades (e.g., pole inspection and replacement) required to construct the communications and telemetry systems in accordance with applicable distribution system engineering standards. Establishing the secure digital network over which distribution system equipment transmits data is essential for safe distributed renewable energy integration and control, while enabling functionality that supports reliability, resiliency, power quality, and energy efficiency. ComEd prioritizes investments within this program according to historical feeder performance, existing communication capabilities, and feeder configuration.

- The **Cable Replacement** programs consist of replacing aging and deteriorated URD, mainline, and network secondary cable populations and designs across selected circuits. The URD cable replacement program currently targets a risk population of bare concentric Crosslinked Polyethylene (XLPE) cable installed from 1966 to 1985, which historically has accounted for approximately 90% of ComEd's URD cable failures to date. The industry was not aware that moisture, electrical voltage stress, and imperfections within the cable structure could combine to degrade the cables and cause failures after only 10- to 15 years in service. This cable had a nominal useful life of 30 years and has a disproportionately higher risk of failure as it approaches 40 years of service. As the 1985 vintage cable approaches the 40-year service milestone in 2025, the need to accelerate replacement is anticipated, and this first population is targeted in the current plan to be fully replaced for current known volumes by year-end 2026. The mainline cable replacement program targets deteriorated and aging bare concentric XLPE cable that exists in ComEd's underground grid in addition to the replacement of mainstem cables which have been demonstrated to be compromised through environmental seal breach or thermographic indication. The network secondary cable replacement program targets replacement of butyl rubber secondary cables and other obsolete designs which present greater reliability, fire, and failure risks in the network system and replaces them with a modern "low smoke" cable design. Investments in mainline and URD cable replacement have a direct impact on corrective maintenance costs and reliability. The programs use advanced analytics to prioritize scope on a yearly basis to address the highest risk cables first.

- The **1% Worst Performing Circuit**, **Customer Target,** and **CEMI** programs identify and design targeted solutions to address respective performance by cause. The 1% circuit program focuses on the identification of the outage drivers that caused the poor circuit performance in either SAIFI, CAIFI (Customer Average Interruption Frequency Index, representing the average number of interruptions for those customers who experience interruptions during the year), or CAIDI. The customer target program focuses on identifying the core drivers for the outages that caused the respective customer's reliability experience to exceed the service reliability target of more than 7 interruptions or more than 18 hours of outage duration in three consecutive years. And the Customers Experiencing Multiple Interruptions (CEMI) program focuses on the core causal drivers that drove the respective customers to experience multiple interruptions. For each program, the reliability engineering group designs solutions to address the core causes and instill resiliency to improve future performance for the targeted circuit areas most efficiently and prudently. The investments for these programs are refined each year based on prior years' "candidates," and those circuits and customers who demonstrate one or more years of the select reliability indicators determine the volume of design solutions planned for.

- The **Circuit and targeted resiliency** programs are intended to proactively enhance the resilience of entire distribution circuits or targeted "pocket" areas of a circuit with a high risk of failure by rebuilding to a more robust design standard (e.g., NESC Grade B construction). These improvements entail storm hardening design, rebuild, relocation, or undergrounding of existing lines to withstand impacts from weather events without sustaining interruptions. Circuits and "pocket" areas are identified and prioritized via analysis of outage history, material condition, and design elements. Specific improvements include: 1) building new ties to neighbor circuits to facilitate reconfiguration and service restoration; 2) implementing targeted conversion of overhead lines to underground distribution or using overhead spacer cable in areas where vegetation is a problem; 3) building new URD loops to provide alternative power delivery paths to residential customers; 4) reinforcing overhead lines by reducing the average length of spans via the installation of midspan poles; and 5) using alternate and more resilient materials for poles, structures and insulation (e.g., fiberglass, polymer, etc.).

- The **Obsolete Equipment Replacement** program consists of upgrading obsolete or degraded equipment with current designs that incorporate critical safety and resiliency needs. Equipment in this category includes legacy protection and switching devices such as porcelain cutouts with slow growth cracking due to manufacturing defects, oil reclosers lacking suspension capability for workforce safety, switch designs for network protectors, and transformers at the end of life, etc. Equipment serving facilities critical to societal resilience is prioritized, and opportunities to bundle this work with other System Performance work are leveraged on an ongoing basis to reduce the cost of equipment replacement.

- The **Societal Resilience Program** focuses on system investments to enhance the resiliency of circuits serving high-impact areas and customers critical to society. This includes, e.g., hospitals, water purification plants, sewage treatment plants, transportation and communication hubs, as well as emergency response facilities. A periodic review is conducted every 5 years for customers included in the societal resilience program. The review includes validation of sources, historical reliability, exposure, critical load points, and existence of temporary service and/or generator deployment plans, as well as a vulnerability assessment.

- The **ATO modernization program** targets the replacement of ATO devices that are obsolete, have no replacement parts readily available in case of failure, and have extended well beyond their manufacturer stated service life to the point where replacement is more cost-effective than continued maintenance and repair. ATO service has been available as optional facilities (under Rider NS) on the ComEd system since about 1960, offering a means to provide two utility sources to critical loads. One source serves as a preferred or primary source, and the other is a “back-up” to automatically restore the critical loads in the event the preferred source has an outage. Of the nearly 1,400 ATOs in operation, approximately 650 were installed before 1990, 80 of which were designed in the 1950s and ’60s. Priority is given to equipment in greatest need of replacement due to parts availability and material condition. Further, among that top priority replacement group, those units serving customers and facilities supporting societal services such as hospitals, water pumping, flood and wastewater treatment, communications, and transportation services are targeted for early inclusion. This investment improves customer reliability by minimizing potential lockouts of sources feeding the units (which interrupts all customers on the units) and potentially avoiding emergency repairs requiring long-duration outages, especially to critical infrastructure.

- The **Remote Network and ATO Monitoring** programs provide remote monitoring capabilities to network equipment, secondary manhole cable, and ATOs. This enables proactive, condition-based maintenance through improved visibility of asset health between period maintenance cycles and enables early detection of problematic equipment, thus mitigating potential outages before they happen and saving on corrective maintenance costs. Remote equipment monitoring can be coupled with advanced analytics to enable predictive maintenance algorithms for early identification and mitigation of potential asset health issues. In the case of remote ATO monitoring, remote monitoring is also essential to provide real-time status of ATO configuration and assurance to the ATO customer that their service is intact and functional.

- The distribution **Phasor Measurement Unit (PMU)** program supports the enhancement of grid visibility and situational awareness. These devices synchronously measure electrical parameters (voltages and current waveforms and corresponding phasors) along feeders and lines throughout the distribution grid (outside substations). The data provided by these devices increases grid visibility for monitoring, protection, and control, and enables a controllable, dynamic, safe, and responsive grid, capable of adapting to changing conditions.

- The **DER Management System (DERMS)** program consists of the deployment of DERMS solutions. DERMS are management and monitoring systems that facilitate safe and effective DER integration into the grid. Specifically, along with ADMS, DERMS increases an operator’s real-time visibility into the status of DER and allows managing DERs and grid assets in real-time to mitigate issues and improve overall system performance.

3.3.2 Corrective Maintenance

The proposed Corrective Maintenance investments are intended to repair or replace deteriorated, damaged, or obsolete distribution and substation assets in areas that were not targeted by recent previous investments or in areas affected by emergencies and storms. Benefits will include continuously improving day-to-day safety, reliability, and resilience, and restoring service after emergencies and severe weather events.

- The **Substation** investment plan is the emergent spend to repair or replace failed or defective substation equipment to restore the system to its original operating condition while maintaining reliability and resiliency. Its scope comprises transmission and distribution equipment within substations, plus associated facilities, including:

    - Emergent equipment replacements, such as transformers, breakers, switchgear, bus work, relays, supervisory control, and data acquisition (SCADA), grounding, lightning protection, batteries, and chargers;

    - Facilities maintenance and repairs (building doors, HVAC, roofs, elevator, drainage/sump pumps, switchyard grating, fences, and gates);

    - Fire protection system maintenance, including detection and suppression systems;

    - Substation security maintenance;

    - Substation auxiliary systems that support substation infrastructure (service level power components, lighting, monitoring equipment); and

    - Wood pole replacements with fiberglass or steel (includes light, aux power, feeder, and 34/12kV poles).

  The category uses historical three-year averages of volumes and hours to develop the budget and factors in equipment material condition as part of the prioritization process.

- The **Transmission - High Voltage Distribution (HVD)** investment plan is comprised of investments that include emergent and scheduled repairs or replacement of overhead and underground HVD equipment to restore the HVD system to its original operating condition while maintaining reliability and resiliency for our customers. Investments include repairing or replacing cable, joints, terminations, pipe coatings, corrosion and cathodic protection systems, wood structures and accessories, insulators, and conductors. The annual budget is based on historical spend and factors in equipment material condition as part of the prioritization process.

- The **Distribution** investment plan is currently comprised of the following program investments to address the necessary maintenance volumes based on historical trends and asset life and performance trends to maintain necessary safety and reliability:

    - **Storm** costs address the critical investment necessary to respond to and restore the system's health and integrity following annual weather events. ComEd derives the investment by projecting prior years' actuals with anomalous events removed.

    - The **Distribution Pole replacement and reinforcement** program addresses replacement and restoration of distribution wood poles which have been demonstrated in inspection to have fallen below the NESC strength requirement for the grade of construction. The planned investment is designed based on historical inspection failure rates by area across the planned inspection volumes and areas in the coming years. The planned inspection cycle is aligned to the industry recommended interval of 10 years for the decay zones, within which ComEd's service territory lies as outlined in RUS bulletin 1730B-121.

- The **Distribution Transformer**, **Overhead and Underground Facility Replacements** and repairs, **Cable Fault Repair**, and **Municipal Streetlight Repair and Replacemen**t programs are fundamental to the continuous maintenance of system safety and reliability. More than 90,000 average annual repairs and replacement tasks are performed throughout the system, with the investments planned based on historical trends adjusted for planned impacts of the other system investments.

- The **Distribution Line Clearance** program addresses primary and secondary voltage clearance concerns identified during circuit inspections which are not emergent hazards (as those are corrected or de-energized immediately).

- The **Distribution Vault Structural Repairs** and **Vault Roof Replacements** programs are planned to necessarily repair and replace those elements identified during preventative maintenance inspection programs to maintain the safety and reliability of distribution vaults on the system. The vault roof program is adjusted annually to address replacement of all vault roofs receiving a ComEd structural grade of Cat 1, which is major deterioration and section loss, and work down the number of Cat 2 graded roofs, which are those exhibiting advanced section loss, deterioration, spalling, exposed rebar and delamination, to keep the overall plant risk management and control the annual inflow of Cat 1 roofs.

- The locating and marking of underground distribution facilities for the digging program is a critical investment that ensures the safety of those digging for our projects and all projects performed by others throughout our service territory. The investment is planned in accordance with current contracted rates and trended volume projections by location type.

- The customer investigations and system operation investments are those in corrective maintenance that do not contain a capital component but represent the substantial fundamental investments and resource planning to respond to both customers' needs and system needs to maximize the reliability and optimize performance. These investments are planned based on the trending prior years' requirements.

3.3.3 Capacity Expansion

The proposed capacity expansion investments are intended to address system growth and configuration needs. These investments support load growth while achieving multiple objectives such as increasing the resiliency of the grid by reducing the impacts of low-frequency, high-impact events through removing single points of failure and increasing operational flexibility. An example of a load-driven investment could be a transformer upgrade through the summer-critical program, which would be identified through ComEd’s annual planning cycle where loads are observed, validated, forecasted, and solutions are identified, challenged, and selected. Other examples of investments in this category include targeted resiliency improvement, voltage conversions, substation design improvement, and construction of new substations improving reliability and resiliency, as well as a voltage optimization program that improves grid efficiency in coordination with system planning. The upgrading and construction of substations, which are multi-year projects, are key investments to address more than load growth and asset condition requirements. These investments also address reliability, resilience, DER and beneficial electrification integration, flexibility, and extreme weather preparedness needs by providing operational flexibility to adjacent substations and areas. As new technologies emerge as options for grid planning, they should be considered as solutions to grid needs as long as those solutions comparably and cost effectively address the planning objectives. This could include evaluating and installing technologies such as battery energy storage systems (BESS) as NWAs to meet the needs of localized load growth where they are the optimal solution to meet grid needs.

- The **Summer Critical** program consists of the relief work identified through the Area Planning process to ensure the distribution system is designed to meet the forecasted peak demands on the system. These projects are to address identified system design criteria violations such as forecasted overloads. The scope of work can range from phase balancing to installing new feeders or substation transformers to installing a new distribution substation.

- The **Target Reliability** program addresses areas of the system that are at higher risk due to system configuration. Projects include retiring obsolete equipment while re-designing the configuration of the grid in the area, increasing operational flexibility of the substations. Also included are projects to reduce the risk of distribution substations served by radial tapped sources with single points of failure. These projects reduce the impact in the event of a loss of source to the substations. Projects range from adding tie feeders served by external substations to be able to provide a backup source to installing new diverse 138 kV lines to provide an alternate source to the substation.

- The **4 kV to 12 kV Conversion program** addresses approximately 1,100 4 kV feeders on the ComEd system. Strategic conversion of 4 kV to 12 kV will provide the benefit of increased operational flexibility and hosting capacity, which could be especially significant with the increased penetration of DER as well as enable beneficial electrification. The 4 kV to 12 kV Conversion program prioritizes areas with obsolete equipment, asset health, and system configuration. The increased operational flexibility that this project provides can also enable higher levels of reliability. Upgrading to 12 kV provides a greater number of switching options with adjacent feeders, which allows for faster restore times from outages and more flexibility for maintenance. The conversions will further enhance reliability by allowing the addition of DA devices.

- The **VO program** will continue to add customer energy savings through control of voltage regulating equipment and serving customers at slightly lower service voltage to increase efficiency.

- The **Bus Reconfiguration program** addresses legacy designed substations and converts these distribution buses from a straight bus to the current standard ring bus configuration. The new configuration provides added operational flexibility by enabling maintenance work on the bus while maintaining feeders in normal configuration. As part of this program, outdoor busses are converted to busses that are housed in indoor switchgear buildings, which provide additional increased reliability and resilience. There are more than 180 distribution substations with straight buses. This program specifically targets substations where the failure of one bus tie circuit breaker will result in a loss of the substation and prioritizes substations by customer count, stranded load at risk, and asset health.

- The **4 kV Substation Retirement program** targets substations that supply 4 kV areas. These 4 kV substations can have obsolete equipment on the system and out of date protection schemes. The program calls for an assessment of these substations to determine a best plan of action for these assets. Options include refurbishing and converting them to 12 kV substations or retiring the substation. Retirement would include 12 kV buildout from other substations. The 4 kV Substation Retirement program is coordinated with the 4 kV to 12 kV conversion program. The conversions of these 4 kV areas will provide increased resiliency by providing operational flexibility and improved feeder sectionalizing as well as increasing hosting capacity and enabling beneficial electrification.

3.3.4 Customer Operations

While ComEd's deployment of its AMI system is complete, there continue to be capital expenditures to support the normal connection and disconnection of customers as they move in and out of the ComEd service territory, as well as costs to maintain the security of the AMI system. Additional Customer Operations investments ensure that ComEd can continue to meet its evolving customer service obligations, although many of these investments are not part of the grid itself and lie outside of the grid investment planning process.

3.3.5 New Business Connections and Facility Relocation

The proposed investments are intended to address grid needs to interconnect new residential and commercial customers or relocate ComEd electric assets to support Federal, State, Country, and Municipal improvement projects. These investments are required to relocate, modify, or expand the grid when necessary to serve ComEd customers.

3.3.6 Investments Planned in Information Technology

ComEd has proposed the implementation of IT infrastructure and systems that support or enable these distribution investments. Examples include advanced analytics platforms, as well as control and information systems that leverage the high-resolution and granular data and situational awareness provided by intelligent devices to understand better the performance of the overall system and individual grid assets. This can help, to the extent possible, anticipate issues and prescribe and execute solutions to prevent or correct performance deterioration. These systems also: 1) help reduce the impact of outages (automatic grid reconfiguration leads to shorter duration of outages and fewer customers affected); 2) enable the integration of greater amounts of DER (real-time monitoring and control help to optimize DER operation); and 3) improve customer experience (easily understandable information on interactive platforms increase the effectiveness of customer engagement). As more elements of ComEd's grid planning activities are digitized (to address overall digital transformation needs), IT infrastructure and systems will become even more critical to enabling the capabilities required by the Clean Energy Law.

A few specific program examples follow:

- The **Advanced Distribution Management System** (ADMS) program consists of the deployment of a system of integrated computer-aided applications and tools used by operators to monitor, manage, and optimize distribution grid performance. The ComEd ADMS solution will consist of management and control solution sets:
    - **D-SCADA:** distribution control system architecture that uses computers, networked data communications, and graphical user interfaces for high-level distribution process control and supervisory management.
    - **OMS:** the capability to efficiently identify and resolve outages and to generate and report valuable historical information regarding ComEd customer service interruptions and restoration status.
    - Further applications to support high penetrations of distributed technologies are not yet fully developed but will be necessary to support DER integration and the continued safe

and effective operation of the highly distributed grid. These applications include, but are not limited to: fault location analysis; unbalanced load flow; distribution state estimator; contingency analysis; fully integrated operator training system simulator; electronic standard switching request, switch order management; advanced distribution planning functions; time-series data and advanced analytics (e.g., load forecasting); and Geographic Information System (GIS) model correction notification.

- The **one Mobile Dispatch Solution** (oneMDS) program will provide ComEd with a single, unified platform on which to build and deliver work execution, status reporting, and critical data collection solutions for every field organization in the business. The oneMDS Project aims to place all fieldwork onto a common platform, enabling full digitization of paper forms and creating a foundation for mutual assistance within ComEd and other Exelon Utilities. ComEd's status as an Exelon Utility provides a unique opportunity to quickly share resources across utility boundaries to shorten restoration times following significant weather or other low-probability/high-impact events. Establishing a common data platform across all Exelon Utilities allows for seamless execution of tickets and quicker restoration times for ComEd customers. With oneMDS, crews from other utilities can expedite the restoration of ComEd's customers.

3.4 Expected Benefits of Planned Investments

ComEd expects the investments discussed to provide benefits in the following areas:

- Address general and specific capacity, reliability, and resilience needs and improve grid flexibility to achieve performance objectives at the system level.

- Support decarbonization through increasing ability to integrate DER and beneficial electrification by enabling grid capabilities and execute automated control actions to prevent or correct issues that can impact customers and assets.
    - Facilitate integration of customer-owned DER, which results in reductions in both the time and the cost for customers to connect their distributed resources.

- Address legacy design features that are not suitable for modern operation requirements. Doing so enables customers and communities to decarbonize through electrification of transport, heating, and industrial equipment.

- Reduce economic losses to businesses, and disruption to personal lives, caused by interruptions of electric service.
    - Customers experience fewer outages because of system hardening and asset health analytics, which enable ComEd to track deteriorating assets and dispatch maintenance crews to repair or replace these assets before they cause an outage.
    - When ComEd crews are required to drive to neighborhoods to restore service, the restoration occurs faster because the crews arrive with better information regarding the causes of the outage from sensors, improvements to circuit designs, and controls.

- Evolve the grid toward a more efficient system as ComEd replaces poorly performing and/or outdated equipment with new equipment and higher voltage feeders and distribution controls that improve the efficiency of the system.
  - Using the investments in sensors and analytics to optimize maintenance practices, ComEd can mitigate O&M expenditures and extend the lives of existing assets.
  - Improve energy efficiency through voltage optimization.

The Clean Energy Law will also impact some of the priorities targeted by the Capital Investments Proposal in ways that have yet to be determined. Inputs provided by stakeholder engagement may help define additional priorities to augment or alter the way that the proposal evolves in the areas discussed in this Capital Investments Proposal.

3.5 **Summary of Planned Distribution System Capital Expenditures**

The graph and table below represent a preliminary capital investment proposal of ComEd's distribution system plant additions for the years shown for the purposes of MYIGP Workshop discussions. The dollar amounts shown are not to be considered an indication of ComEd's expected rate base. Furthermore, ComEd is still analyzing the demands on the grid and associated funding requirements as it relates to the objectives of Illinois' Clean Energy Law, updates from upcoming workshop discussions, and impacts from additional factors up to and including requirements introduced by other laws such as the Infrastructure Investments and Jobs Act (IIJA). For those stated reasons, ComEd expects the planned distribution system investments shown to be refined in coordination with ComEd's annual grid planning process. For individual projects where construction occurs across multiple years, the full amount of the distribution system investment is reflected within the year in which the project is placed in-service.[28]

[28] While the Clean Energy Law requests information regarding planned investments for the 5-year period following the year in which the workshop is held, which in this case would be 2023 to 2027, as the Clean Energy Law also recognizes, ComEd is subject to financial and system planning processes, and may not have reliable information for the later years in that time frame. In this instance, ComEd does not yet have any information related to 2027.

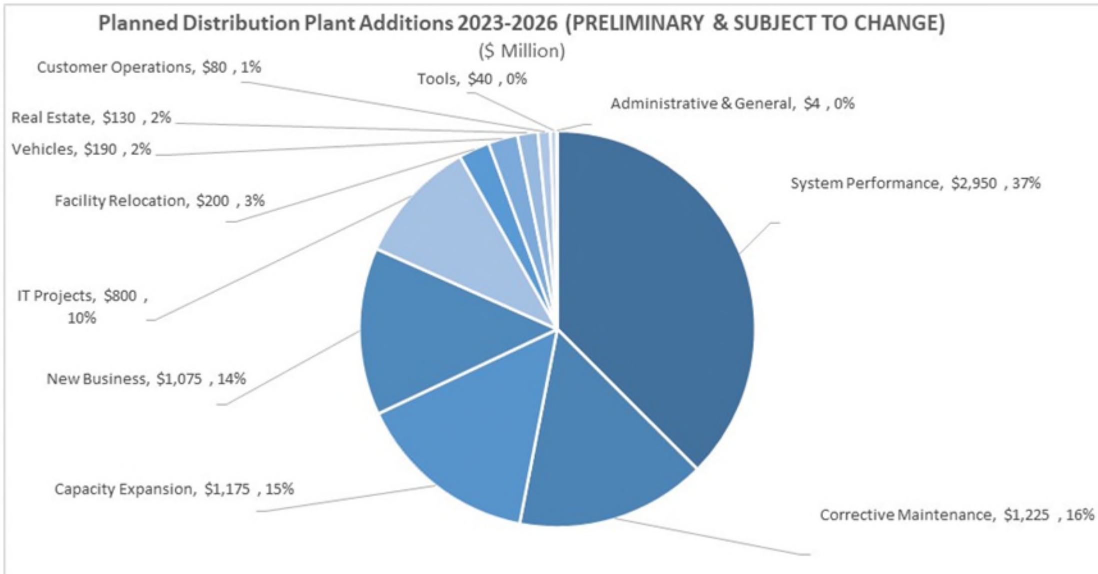

Figure 3-13. Estimated Planned Distribution System Plant Additions 2023-2026

Table 3-1. Estimated Distribution Plant Additions by Investment Category

Estimated Distribution Plant Additions for all Investment Categories with 2023-2026 Total Spend of $2M or Greater *(Sorted by 2023-2026 Total)*					
Investment Category	**2023 ($M)**	**2024 ($M)**	**2025 ($M)**	**2026 ($M)**	**2023 - 2026 Total ($M)**
System Performance	675	675	750	850	2,950
Corrective Maintenance	300	300	325	300	1,225
Capacity Expansion	250	250	225	450[29]	1,175
New Business	325	250	250	250	1,075
IT Projects	300	150	200	150	800
Facility Relocation	50	50	50	50	200
Vehicles	60	50	40	40	190
Real Estate	30	20	10	70	130
Customer Operations	20	20	20	20	80
Tools	10	10	10	10	40
Administrative & General	0	1	1	2	4
Total	2,020	1,776	1,881	2,192	7,869

The chart and table above include estimated plant additions related to distribution system assets and the allocated share of General & Intangible assets and exclude any coupled O&M investments such as Preventative Maintenance (including the vegetation management program) and the O&M component of Corrective Maintenance. The coupled O&M dollar amounts are excluded from the chart and table above as those spends do not include any distribution rate base plant additions.

3.6 Concluding Remarks

ComEd's Capital Investments Proposal establishes a foundation for a larger Grid Plan that will help the State, customers, and stakeholders meet collective goals. A grid with renewed capabilities is required to integrate clean energy technologies to mitigate climate change, provide enhanced resiliency, improve air quality, and uplift communities. This grid must leverage the best practices developed in the industry over more than a century of disciplined work, as well as the new opportunities made possible from clean energy technologies to meet evolving societal needs.

ComEd welcomes the ensuing workshops and discussions with stakeholders on realizing these goals.

[29] 2026 Capacity expansion estimated plant additions driven by two multi-year new substation investments that are projected to be placed in-service within 2026.